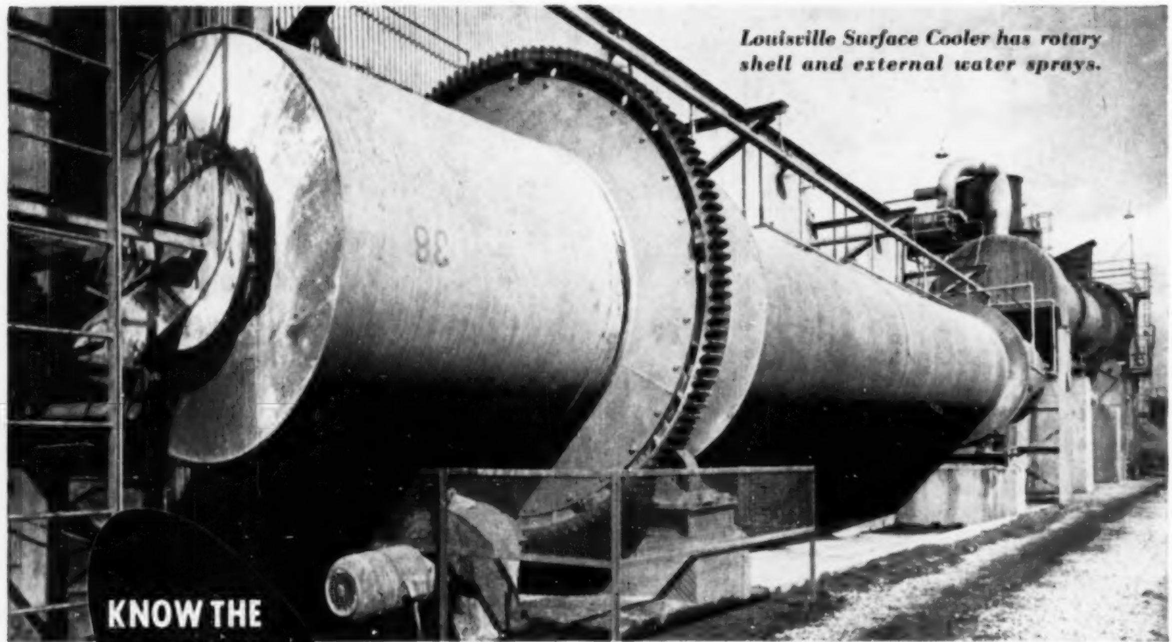
OCTOBER 1953

Chemical Engineering Progress

PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

See Louisville for
CREATIVE COOLING ENGINEERING

Louisville Cooler does satisfactory job at low cost for nationally known chemical manufacturer . . .



Louisville Surface Cooler has rotary shell and external water sprays.

KNOW THE RESULTS before you buy!

. . . cooling lumpy calcined material from 1800° Fahr. to 150° Fahr. for further processing. Gentle mechanical handling required to minimize decrepitation.

Each Louisville cooler is "*job-fitted*" to your special problem—to make your cooling operations effective—to assure dependability of performance that will make the cooler operation pay.

Call in a Louisville engineer for a complete cooling survey. Based on his experience he will recommend one of the three standard Louisville types, a modification, or an entirely new design. *The performance will be pre-determined.* You'll know the results before you buy . . . and the results *must* be better! Write for complete information today.

3 types of Louisville Coolers

- **Surface Cooler**
- **Water Tube Cooler**
- **Atmospheric Cooler**

Other General American Equipment:
Turbo-Mixers, Evaporators, Dryers, Dewaterers, Towers, Tanks, Filters, Pressure Vessels

PROCESS EQUIPMENT DIVISION
GENERAL AMERICAN
TRADE MARK

Louisville Drying Machinery Unit
Over 50 years of creative drying engineering
GENERAL AMERICAN TRANSPORTATION CORPORATION
Dryer Sales Office: 139 So. Fourth Street
Louisville 2, Kentucky
General Offices: 135 South La Salle Street, Chicago 90, Illinois
Offices in all principal cities
In Canada: Canadian Locomotive Company, Ltd.
Kingston, Ontario

Chemical Engineering Progress

OCTOBER, 1953

Volume 49, No. 10

Editor: *F. J. Van Antwerpen*

OPINION AND COMMENT

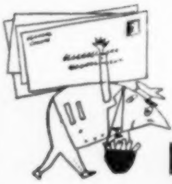
ENGINEERING SECTION

NEWS

Advertising Manager: *L. T. Dupree*

Published monthly by American Institute of Chemical Engineers, at 15 North Seventh Street, Philadelphia 6, Pennsylvania, Editorial and Advertising Offices, 120 East 41st Street, New York 17, N. Y. Communications should be sent to the Editor. Statements and opinions in *Chemical Engineering Progress* are those of the contributors, and the American Institute of Chemical Engineers assumes no responsibility for them. Subscriptions: U. S. and possessions, one year $6.00; two years $10.00 (Applies to U. S. and possessions only.) Canada $6.50; Pan American Union, $7.50; Other Foreign, $8.00 Single Copies of *Chemical Engineering Progress* older than one year cost $1.00 a copy; others are 75 cents. Entered as second class matter December 9, 1946, at the Post Office at Philadelphia, Pennsylvania, under Act of August 24, 1912.

Member of Audit Bureau of Circulations. *Chemical Engineering Progress* is indexed regularly by Engineering Index, Incorporated.



LETTERS TO THE EDITOR

Where Credit Is Due

In answer to S. Schwartz's comments [Letters "C.E.P.," August, 1953, page 6] on "Sulfur from Hydrogen Sulfide," the contribution of S. L. Nevins and J. S. Gilliam in the development of a circulating sulfur-scrubbing system is indeed meritorious. It deserves recognition as a significant advance and Literature Cited (*10*) in our article describes the Nevins and Gilliam development.

The formation of monatomic sulfur advanced by Schwartz for the higher-than-calculated equilibrium conversions at the "free flame" temperature appears less probable than the explanation proposed by the authors. At free flame temperatures of about 1400° C., the equilibrium partial pressure of monatomic sulfur is only about 2×10^{-4} atm. at a total system pressure of 1 atm. Most likely the key to the high conversions lies in the suppression of the reoxidation of diatomic sulfur to sulfur dioxide.

B. W. Gamson

Great Lakes Carbon Corp.
Morton Grove, Ill.

Human Relations

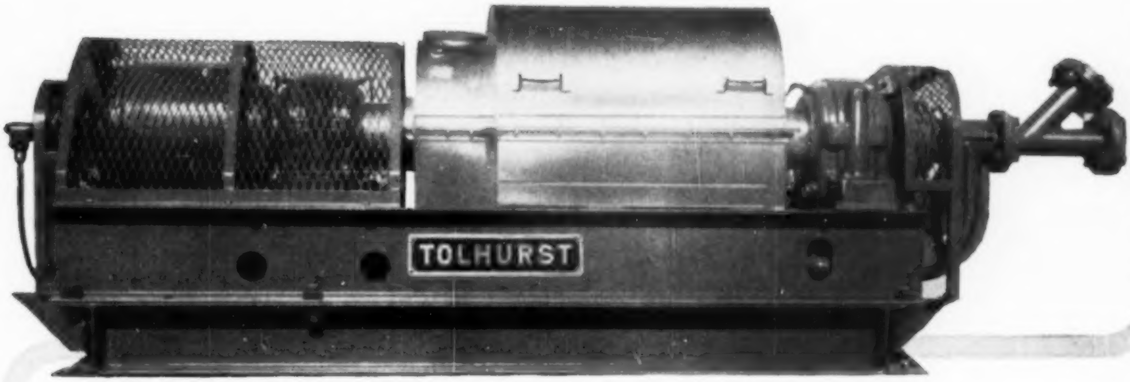
I am writing to offer my sincere congratulations for the article on "The Engineers' Stake and Status in Human Relations," as published in the August issue.

It was good to find how Mr. Demmerle placed his finger on the causes for failure of the engineer (and for that matter the scientist) in human relations. I refer to such of his categories as The Blind Worship of Objectivity, The Need for Real and not just Professional Humility, The Requirement for the Reportorial and not the Scientific Approach in Non-Technical Presentations, and the Distrust of Non-Absolute Standards in Human Contacts.

I like particularly his remark about the scientist's weakness for attempting to argue a person out of an emotionally based point of view. This is certainly a gross, if albeit understandable weakness of the technical person. I am reminded of the Chaplain of the U. S. Senate who opened a morning session with the

(*Continued on page* 6)

can this *NEW* CONTINUOUS CENTRIFUGAL cut filtration costs for you?



See
NEW TOLHURST
CONTINUOUS CENTRIFUGAL
at
CHEMICAL SHOW

NOW YOU CAN GET
A CONTINUOUS CENTRIFUGAL THAT PROVIDES . . .

- **7 different pool depths**
- **Variable beach speeds from 0 to 300" per minute**
- **2000 F x G**
- **Self-cleaning feed chambers**

WHAT CAN THIS MEAN TO YOU?

FOR LONG RUNS ON A SINGLE PRODUCT If your plant runs continuously on a single product, process fluctuations or changes in processing technique need no longer be a problem. The Vari-Beach Drive permits beach speed to be changed instantly, from 0 to 300 inches per minute. Seven different pool depths are available by a simple adjustment of the Vari-Pool Orifice Plates. An available force of 2000 times gravity assures maximum settling rate. This flexibility can mean maximum efficiency in your centrifuging step.

FOR SHORT RUNS ON DIFFERENT PRODUCTS Perhaps your plant runs for awhile on one product, then changes over to another product. Now, for the first time, you can enjoy the advantages of continuous centrifuging. When you change from one product to another, you simply adjust beach speed and pool depth by means of the Vari-Beach Drive and Vari-Pool Orifice Plates and you're ready for the new run. Self-cleaning feed chambers minimize down time when changing products.

FIELD TEST UNITS Ask for details on Tolhurst Continuous Centrifugal available for a 90-day test in your plant.

Tolhurst
CENTRIFUGALS

Division of
AMERICAN MACHINE AND METALS, INC.
EAST MOLINE, ILLINOIS

LETTERS TO THE EDITOR

(Continued from page 4)

words: "When we are unable to convince let us be willing to persuade." This might indeed be a worthy catch line for the excellent presentation under discussion.

CHARLES H. PRIEN

Head, Chemistry and Chemical Engineering Division
Denver Research Institute

Aye, We Do Protest!

We would like to register a protest to the continued appearance in Chemical Engineering Progress of technical papers by installments. An occasional very long paper could possibly be printed at an earlier date by breaking it up, but the added inconvenience and annoyance to the reader do not justify this as a continuing practice. This is especially true when reference must be made to technical papers appearing in several previous issues. The major annoyance is well illustrated by the following quotation from "C.E.P.," March, 1952, p. 146: "Part II, to be run in an early issue, will contain Notation, Literature Cited, remaining figures and all tables."

C. J. DOBRATZ
T. E. DRISKO, JR.
J. FRANK VALLE-RIESTRA
ELDRED L. DANCE
EUGENE S. DEHAVEN

Dow Chemical Co.,
Pittsburg, Calif.

"To be continued" or "Part II will be run in an early issue" at the end of an article is the bête noire of some of our readers, who need the entire story in one issue. It is to be regretted that such needs cannot always be satisfied, for when an article runs beyond the normal length of six to eight pages, it must be broken up into installments so that chemical engineers with other interests will have something to read in their field. Diversity of subject matter is one of our main objectives, and the printing of an article of the length just referred to militates against the fulfillment of that purpose. Someday when income allows us to have a technical section of many more pages, we may not have to continue stories but as of now we want the book to be of maximum interest to a maximum number of readers.

THE EDITOR

A "Who's Who Wanted"

Please continue the biographical sketches of suggested nominees in "C.E.P." in future years.

WILLIAM S. WOOD

Springfield, Pa.

Another leading manufacturer using

DURCO

Chemical Service Valves

CHEMICALS FOR INDUSTRY

ROHM & HAAS COMPANY

WASHINGTON SQUARE, PHILADELPHIA 5, PA.

Representatives in principal foreign countries

These Durco Type B Valves have been in sulfuric acid service at the Bristol, Pa., plant for more than 3 years.

Rohm & Haas Company manufactures plastics, synthetic resins and chemicals for a wide variety of industries. Among the products manufactured at their Bristol plant is Plexiglas, their acrylic plastic. Plexiglas is widely used for outdoor signs, transparent aircraft enclosures, automobile stop and tail light lenses, nameplates for home appliances, and a host of other products.

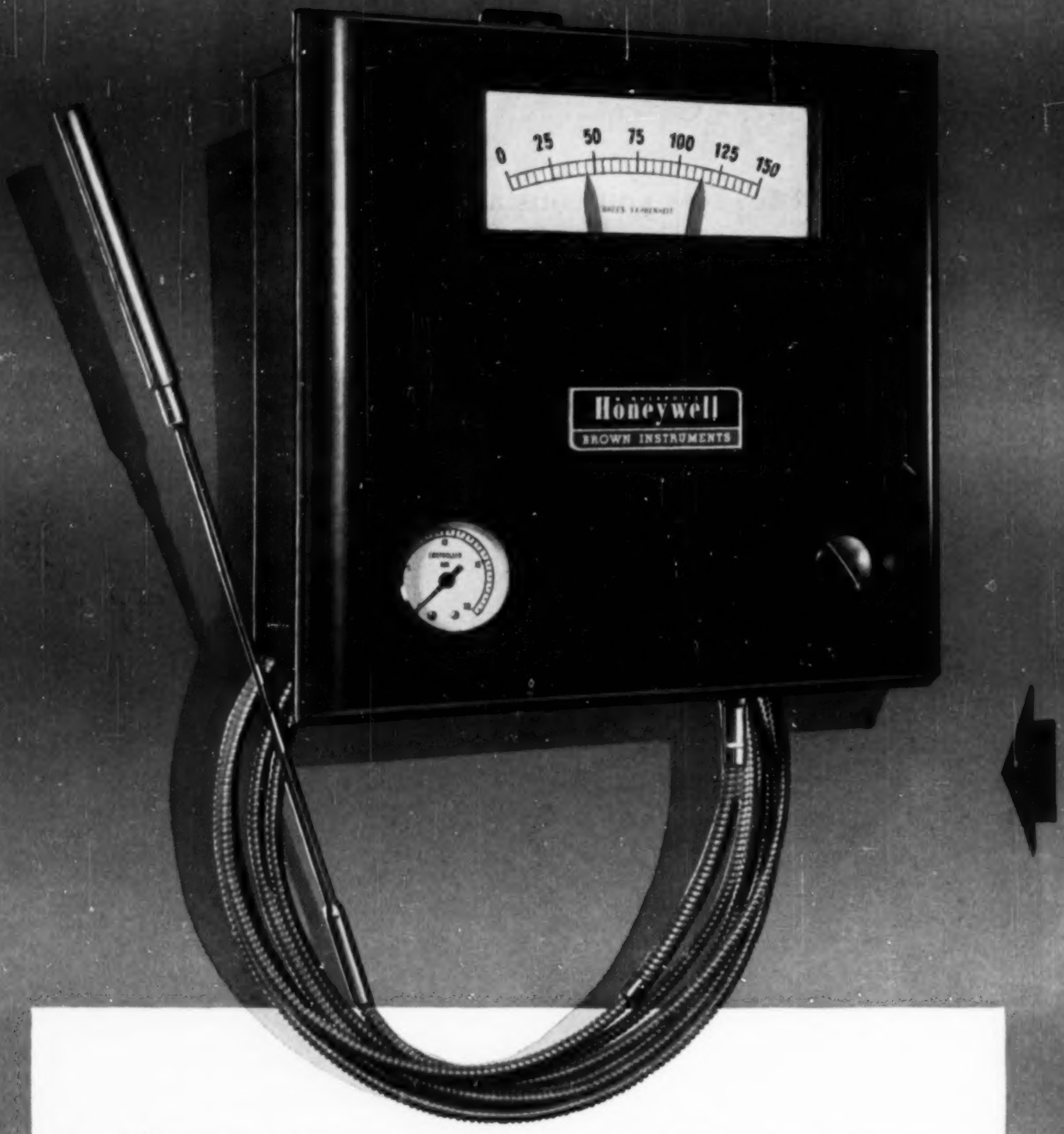
The Durco Type B Valves pictured here have been in service since 1950, handling corrosives ranging from dilute sulfuric acid at 150° F. to a mixture of concentrated sulfuric acid and organic materials at 200° F.

DURCO Type B Valves are heavy-duty chemical service plug valves, either top or bottom lubricated. They are available with flanged ends in sizes from 1" to 8", and with screwed ends from ½" to 2" in a wide range of DURCO corrosion resisting alloys including Durimet 20, Chlorimet 2, Chlorimet 3, 18-8-S-Mo, and others.

Write for Bulletin V/2, and determine how DURCO can help solve your corrosion problems.

DURCO
CORROSION RESISTING ALLOYS & EQUIPMENT

THE DURIRON COMPANY, INC., DAYTON 1, OHIO



Look at these features of the Model 604P5 Thermometer Controller

GOOD READABILITY:
indicates temperature on 4½" scale.

QUICK CONTROL CHECK:
readily visible red control pointer and black indicating pointer.

CONTROL AIR CHECK:
front-mounted gauge indicates air pressure to control valve.

VARIETY OF CONTROL:
direct or reverse acting pneumatic control —either on-off or proportional action.

SELECTION OF RANGES:
23 different temperature ranges, up to 1000°F., in Fahrenheit and Centigrade calibrations, for vapor and mercury bulb systems.

COMPACT DESIGN:
die cast aluminum case 11" x 11", 4" deep; gasketed black plastic cover; practically splashproof. Interchangeable flush or surface mounting on panels of any thickness.

SIMPLE SETTING:
external knob for adjusting control point

NOTED AND QUOTED

What's Sauce for the Goose . . .

Already there is a mounting body of evidence to suggest what the outcome will be if science hesitates to extend itself and withdraws into the security of only those 'facts' that can be weighed and measured, or entered in the coding devices of electronic computers. In a mass-educated society people crave enlightenment . . . Much of the faddist and crank behavior that perplexes . . . the scientific community, often giving it the sense of being surrounded by a sea of irrationality, belongs in a grouping . . . titled 'vacuum phenomena.' . . . Whenever large numbers of individuals are willing to make themselves ridiculous in the face of orthodox opinion, at a cost of which they are quickly made aware, there is likely to be an element among their motives that is not ridiculous at all. Much harm was caused by the . . . mental invalids who claimed to have seen flying saucers, but much harm was also caused by scientists who persisted in offering explanations that did not explain, insisting that no others were needed and labeling all disagreement hysterical . . .

Eric Larrabee
Harper's Magazine

A Practical Theorist

Despite his achievements in science, the University professor is still regarded as an impractical person who never comes to grips with realities of a hard world that demands not theories but dividends earned by reaping machines, electric lamps, steam engines, and television. No one is so impractical as the practical business man, a sentimentalist who believes that what was good enough for his father is good for himself and who does not therefore welcome technical innovations and changes. There is nothing sentimental about a university theorist. He is far more ruthless than any Tamerlane, not for the sake of cruelty but for the sake of objectivity. If a theory no longer works he either modifies it until it does work or casts it aside for something better. This is the very essence of practicality.

Waldemar Kaempffert
Explorations in Science

There is a choice before us between free and design research, or as I see it, between supporting the man or the experimental design. Let us support the man.

Curt P. Richter
Science

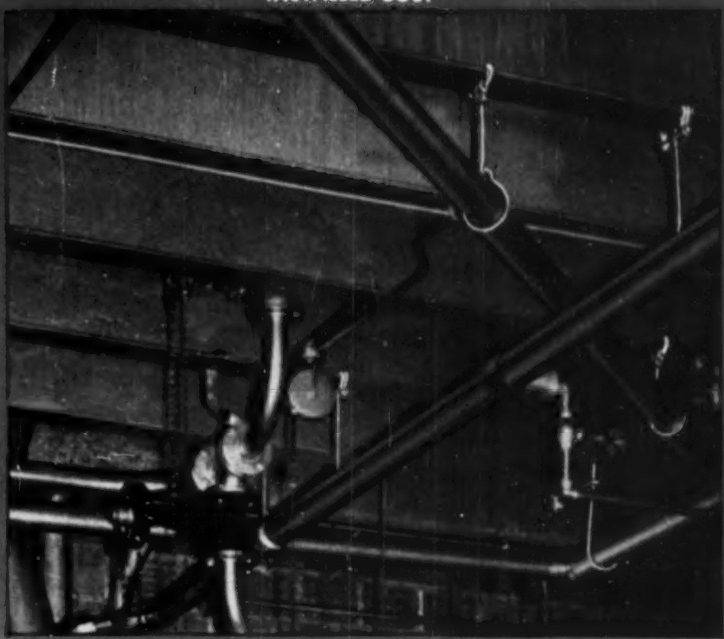
take a closer look at

Light-Weight STAINLESS PIPING

Schedule 5 and Schedule 10

INITIAL COST

INSTALLED COST

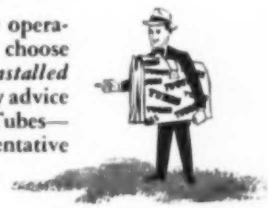


The *initial*-cost economy of Schedule 5 and Schedule 10 stainless pipe is always attractive but only pays dividends to the careful buyer. He is willing to remember that light-weight pipe frequently requires added supports or hangers and always requires special fittings. He also remembers that alignment problems may require a longer installation time. Therefore, he balances the attractive *initial* cost against *installed* cost.

The buyer also thinks of the adaptability of new piping to existing lines and possible future requirements such as increased operating pressures.

B&W manufactures all the standard pipe size schedules in a complete range of stainless steel grades. Thus, a buyer can obtain stainless pipe to meet any and every individual requirement.

It will pay you to analyze your operating requirements carefully and choose your stainless pipe on the basis of *installed cost* rather than *initial cost*. For any advice on stainless pipe or tubing, Mr. Tubes—your impartial B&W Tube Representative—is always on call.



B&W SEAMLESS and WELDED TUBES

THE BABCOCK & WILCOX COMPANY

TUBULAR PRODUCTS DIVISION

Beaver Falls, Pa.— Seamless Tubing; Welded Stainless Steel Tubing
Alliance, Ohio—Welded Carbon Steel Tubing

TA-1761 (G)

Opinion and comment

SECRET SELECTIVE SERVICE?

Something is seriously amiss with the selective service practices of this country. An unwelcome change has been detected in the attitude and draft deferment practices of the selective service officials by the Engineering Manpower Commission. Since December of last year, according to the Engineering Manpower Commission of Engineers' Joint Council, there has been an over-all reduction of one sixth in industrial occupational deferments. At the end of 1952 there were in this country 31,000 occupationally deferred selective service registrants and by June 30 of this year the number stood at 25,797.

Full details of the change are not apparent since no directives have come out of selective service which spell out a change in procedure. But the Engineering Manpower Commission feels that there seems to be some sort of understanding that occupational deferments should not extend beyond a two-year period *regardless of the work being done by the registrant.*

How much better it would be if the selective service director were to inform employers and employees too of any change in policy. It is always easier to plan, of course, if one knows official attitudes. However, if there has been a change, and if there is a secret understanding by selective service officials that no man shall be deferred more than two years, we believe such secret diplomacy can do more lasting damage than an out-and-out avowal of any change in policy.

The number of men who have been deferred by selective service for occupational need is minor compared with the whole manpower pool. Out of some thirteen and one-quarter million of draft age, only 31,000 have been deferred. Surely this is a small enough segment to be made available to industry and an unspectacularly small segment to be singled out for special secret treatment.

If this country is to have universal military service, or universal military training, it would be better if the electorate knew it. If the attitude of selective service is now that every boy of draftable age must serve his allotted term in the army, let it say so, and let the people plan accordingly.

As for the proper action under such a threat of the drafting of key men, the advice to industry is to continue to fight for each man and to appeal each case important enough to warrant such a protest.

These are difficult times for the American people. We not only suffer abroad from secret diplomacy—we are very much in the dark about our own negotiations—but how much more difficult it is when we do not even know domestic attitudes and policies. Is it any small wonder that a peculiar type of lethargy has settled over the average citizen of the United States? The right of people, the right of individual citizens, the right of groups, and the right of industry to know is unassailably basic and primary. It should not be violated by dicta.

THE CHEMISTS' CLUB LIBRARY

The Chemists' Club Library is making its annual request for maintenance funds to supplement the amount available from the club income. A valuable source of research for the engineer and other scientists, the library makes available current and back issues of some 260 technical publications. There are 50,000 volumes, including standard foreign and American reference works, on the library shelves.

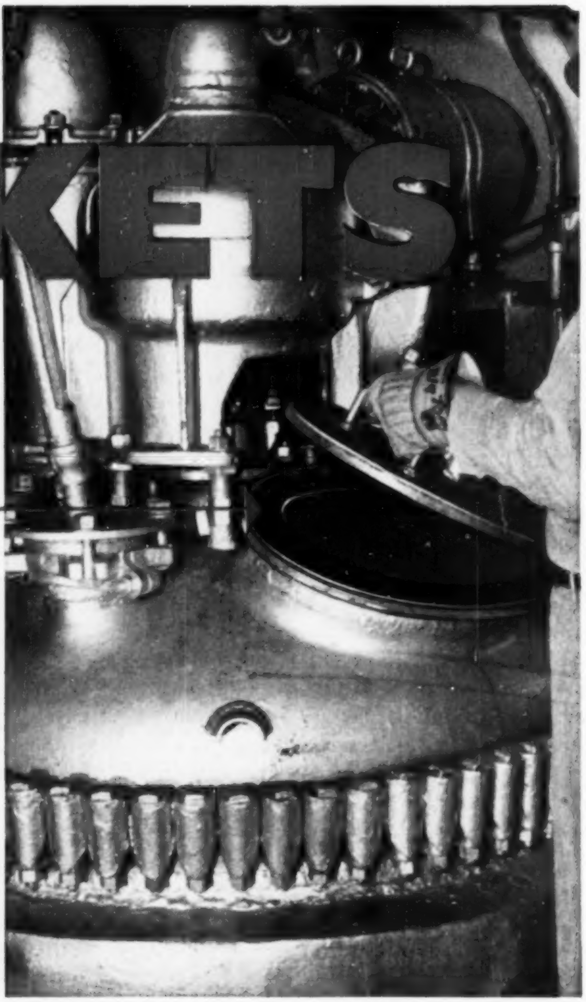
Because the amount of published technical information is constantly growing, the Library funds must be increased. The last Annual Index to *Chemical Abstracts,* for example, the Library reports is as large as the first Decennial Index. To keep the Library abreast of this flow of literature, W. F. George, president of The Chemists' Club, appeals for funds from industry and individuals whose work depends upon the published work of earlier investigators.

" 'To search the literature,' " Dr. George continues, "becomes a more formidable task with each new research project. Without a living, growing Chemists' Club Library, it can become a prohibitively time-consuming and costly prelude to progress. Without a growing Chemists' Club Library the day could come when thousands of intermediate reactions and processes would have to be painfully worked out from a blank sheet of paper. Conceivably, without a repository of yesterday's accomplishments, tomorrow can be shrouded in a descending veil of chemical darkness.

"That we and our industry have prospered beyond belief is due in great measure to the unimpeded flow of technical information upon which each new project could be evaluated . . . . Let's be certain that generations yet unborn have access to the technical background of today's operations."

Tough GASKETS

FOR TOUGH JOBS ARE MADE WITH TYGON



TYGON GASKET — in service against 85% acetic acid, at 160°-175°F lasts over a year compared to a few weeks' service from rubber. Photo courtesy Hoffman-LaRoche Inc.

One sure answer to tough gasketing problems is the versatile corrosion-resistant TYGON family of plastic compounds. For, TYGON not only resists acids, alkalies, oils, greases, some solvents, and water — but, is strong, resilient, abrasion-resistant and light in weight. TYGON is also impermeable, non-contaminating and non-oxidizing. TYGON can be used for virtually any gasketing job in chemical processing and general industrial equipment — wherever positive, enduring seals or separators are required. For food and beverage uses, special non-toxic compounds are also available.

For service as gasketing, TYGON is made in a number of standard compounds, translucent or glossy black, which offer a range of physical, electrical, and chemical properties for almost any application.

TYGON gaskets can be die-cut from calendered or press-polished sheets ($\frac{1}{64}''$ to $\frac{1}{2}''$ thick); can be molded in practically any size or shape; or, can be extruded as tubing, solid cord, or channel in continuous lengths.

Write today, for further information and technical assistance on the use of TYGON as gasketing. Ask also about the other uses of this versatile plastic that can help you combat corrosion.

TYGON TUBING

fully flexible, glass-clear, mirror-smooth for safe, speedy transmission of liquids, gases and semi-solids.

TYGON TANK LINING

long lasting, heavy duty sheet TYGON to withstand virtually all chemicals.

TYGON PAINT

quickly applied, fast drying protection against corrosive fumes and spillage.

TYGON
THE VERSATILE CORROSION-RESISTANT
PLASTIC

VISIT BOOTHS 10-12-14 — NOV. 30 - DEC. 5
24th Exposition of Chemical Industries, Philadelphia

U. S. STONEWARE
AKRON 9, OHIO

344-C

PLASTICS AND SYNTHETICS DIVISION

The A.E.C. or C.W.S. Air Filter

David H. Northrup has been vice-president and general manager of the Filter Division of the Cambridge Corp. since that organization was formed in 1950. He went there from the Carrier Corp., Syracuse, N. Y. Prior to World War II, Mr. Northrup was associated with Armstrong Cork Co. and from 1941 to 1945 he served on active duty with the U. S. Navy with the rank of commander. Mr. Northrup, a native of South Dakota, was graduated from Yale University in 1936.

During the past ten years a new air filter has opened for industrial application an entire new field in air cleaning. For the first time air, essentially free of suspended matter, is attainable at reasonable cost. Though generally ignored because it is almost invisible, air-borne matter is ever present and cannot be considered lightly in many situations, particularly where there is radioactivity. The concentration of particles in ordinary air, is tremendous; there are generally from 5,000,000 to 30,000,000 or even more individual particles/cu.ft. These particles may be dust, fume, or smoke. Dust which consists of solid matter resulting from natural and mechanical processes of disintegration and dispersion, includes mineral and vegetable matter, pollen, spores, bacteria, soot, ash, and both domestic and industrial debris. Fume, which may be either liquid or solid, is produced by chemical action or volatization. Smoke, either liquid or solid, results from combustion or destructive distillation. Most air-borne matter is in the size range of 0.2 to something more than 1 μ, a micron being approximately .00004 in. These small particles often should be removed from the air because they lead to problems in industrial processes. The A.E.C. filter, a strainer type of dry filter, removes practically all of these tiny particles.

As late as the middle 1920's, little thought had been given to air filtration and there were few installations. Historically the development of these air filters began with the production of special filter papers for gas masks and other military uses during Word War II. The protection of military personnel in combat against poisonous dusts and fumes required an intensive study of air-borne dusts and mists and of means for removing them.

Today there are all sorts of air filters and filtering materials, which are generally grouped into five major classifications: (1) electric precipitators; (2) viscous impingement—metal, glass, plastic; (3) dry type—paper, wool, felt; (4) washers; and (5) centrifugal devices. Viscous impingement and dry filters are available in cleanable units or throwaway units. The cleanable ones may be automatic or manual. Washers and centrifugal devices are more generally used for dust collection in areas where there is a heavy dust load.

The filter paper used in the C.W.S.-type filter was developed during World War II for the Office of Scientific Research and Development (OSRD) and the Chemical Warfare Service (C.W.S.) by Arthur D. Little, Inc., in Cambridge, Mass. When this filter paper was first used in gas masks by C.W.S. at Edgewood, Md., it was on the classi-

fied list. In 1946-47 the Atomic Energy Commission became interested in the paper for use in a space filter and started a major development program. In 1950 this filter was declassified and made available to industry.

Removal of radioactive particles is an extremely important function of A.E.C. In the early days there were no filters available in convenient form and size with proper pressure drop. For lack of a better means radioactive particles were removed by brute force from large quantities of air for processing, laboratory hoods, and reactor cooling. If a 6-in. depth of filter medium lightly packed failed to provide the desired cleaning efficiency, either denser packing or a greater depth was necessary. One installation on the West Coast had 6 ft. of filtering medium packed into an exhaust pipe before satisfactory cleaning was obtained. Forcing the air through this filtering medium required such high pressure that compressors instead of fans were used on the exhaust system.

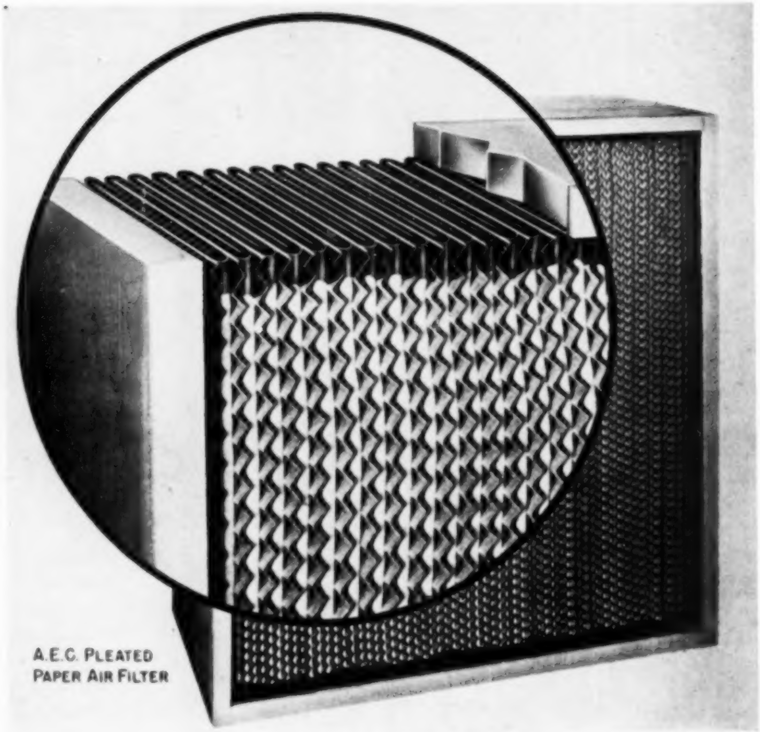


Fig. 1. Detail of end view.

A.E.C. Filter Paper

The secret of the high efficiency of the A.E.C. filter lies in the filter paper which is a soft, feltlike asbestos bearing cellulose paper about 0.034-0.040 in. in thickness. The asbestos fibers, submicroscopic in size, are evenly distributed throughout the paper. The novel feature of this filter is high efficiency in a thin low-resistance sheet.

The rate of air flow in a unit area of filtering surface must be kept low for high filtering efficiency. A multipleated design meets this requirement. The filter paper in one continous strip is formed into a closely pleated construction. The popular size 24 in. square and 11½ in. deep has close to 250 sq.ft. of filtering surface and a rated capacity of 1,000 cu.ft./min. The capacities of other standard size units range from 25 to 1,250 cu.ft./min.

To allow air passage corrugated paper separators are inserted on both sides of the filter. The air passes down the flutes of the separators on one side, through the filtering medium, and out through the flutes of the separators on the other side. The filter package, consisting of the filtering medium and separators, is tightly sealed with adhesive into a frame made of ¾-in. plywood. To avoid leaks a bead of adhesive edges the filter on both sides.

A.E.C. Filter

The A.E.C. filter (Fig. 1) has an efficiency of 99.95% or better based on 0.3 μ particles or a penetration of 0.05% or less. In other words, of every 1,000,000 submicron particles in the air stream entering the filter, fewer than 500 pass through. After 70 hr. of operation in atmospheric dust, fewer than 50 of 1,000,000 particles penetrate because of the gradual build-up of dirt on the filter paper. The fact that filters have a static resistance of 1 in. of water at rated air flow gives this filter the lowest known ratio of resistance to efficiency. It will withstand operating temperatures up to 250° F.; however, prolonged operation at 220° F. or above will deteriorate the filter medium.

Filter Tests

Because of the severe requirements for A.E.C. filters, each is individually tested for leakage by a special method known as a dioctyl-phthalate or DOP smoke test. The two test methods most frequently used on other air filters for general ventilation are: (1) the weight test and (2) the photometric or blackness test.

The weight test, designated in the American Society of Heating and Ventilating Engineers Code, is performed by collecting the dirt which penetrates the filter, weighing it, and comparing it with the amount injected into the air stream. To test in a reasonable length of time, dust concentrations many times that of atmospheric dust must be used. This method is practical for checking the performance of most mechanical filters, but it would be almost impossible to collect a weighable quantity of dust on the downstream side of the A.E.C. filter.

The photometric test, developed at the National Bureau of Standards, measures the discoloration properties of air before and after filtering. Samples of upstream and downstream air of the filter under test are drawn through single sheets of white chemical filter paper. The discoloration of each sheet is measured by checking the amount of transmitted light before and after sampling. By adjusting the size of the spots or the length of time of sampling, equal discoloration is obtained upstream and downstream, and the efficiency of the filter under test is a function of the spot sizes or sampling times. This method is used to rate electrostatic filters with atmospheric dust and can be used to rate lower efficiency filters with reconstituted dusts, each test taking from several minutes to several hours, according to the efficiency of the unit under test. This test would likewise be impractical for the A.E.C. filter.

It is obvious, of course, that every A.E.C. filter produced must be tested. Faulty filters in exhaust systems for radioactive processes would result in the release of radioactive particles and endanger the health of individuals in surrounding areas. In supply air systems

release of particles might destroy an entire batch of an expensive product. The weight and photometric tests mentioned above, which are laboratory rating methods, are wholly inadequate for testing A.E.C. filters both from the standpoint of time and of ability to determine efficiencies on fine particles accurately. For this reason a special dioctyl-phthalate smoke tester was designed and built for quick and accurate efficiency tests. In this machine, which evolved from work done during World War II on screening smokes and on gas masks, fumes are generated from dioctyl-phthalate liquid to give particles of practically uniform size and concentration. For this test the particle size is maintained at 0.3 μ. Where filters are tested in an air stream containing these particles, an instantaneous reading of efficiency can be taken. Actual measurement of the concentration of smoke particles upstream and downstream in the filter under test is made by recording the amount of scattered light when samples of each are passed through a scattering chamber.

The 0.3 μ particle size was selected for use in testing because many consider it the most difficult size of particle to remove. Larger particles are caught in the interstices of the filter medium; smaller particles are subject to the Brownian movement. As a result of random movement, these smaller particles have a tendency to be caught. The 0.3 μ particle seems to conform with the airstream and work its way through the medium.

Figure 2 shows a piece of filter paper removed from a filter which had been in operation for several thousand hours. Because the filters have a large dirt-holding capacity, dirt collected all the way down the pleat. The white stripes occur where the peaks of the separator flutes were in contact with the filter paper. The dirt collected is extremely dark—almost black. These fine black particles are always present in the atmosphere but because of their minute size are generally invisible. However, when concentrated these particles cause trouble in industrial processes and are responsible for the smudging which frequently appears around air outlets.

Figure 3 shows a cross-sectional photomicrograph of filter paper .040 in. thick. Much dirt has built up on this paper, but there has also been a substantial collection in depth. The dirt has penetrated to a depth of approximately 50%, thus leaving a margin of safey of approximately 50%. There is no evidence of any dirt having gone through the paper.

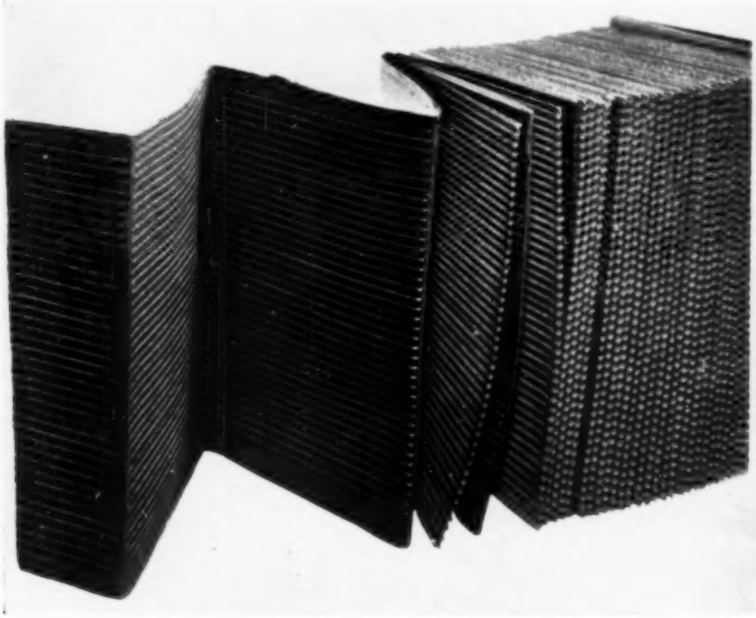


Fig. 2. Filter package after several thousand hours of operation.

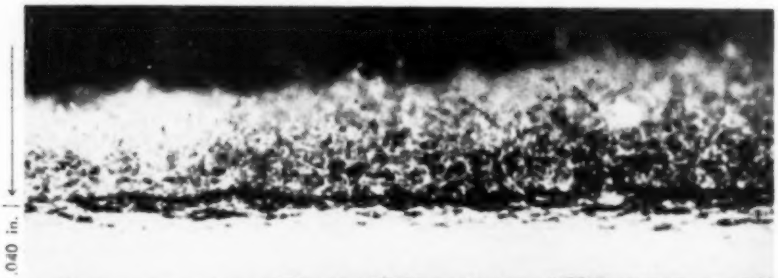


Fig. 3. Photomicrograph of filter paper (cross-sectional view).

Types of Installations

These filters are used in three major types of systems: (1) exhaust air, (2) supply ventilation air, and (3) process air.

Exhaust air uses are those found primarily at A.E.C. sites. However industrial and medical establishments must remove poisonous particles from the air stream before dispensing it to the outside area. In exhaust systems location of the filter depends on the type of application. The exhaust may be filtered from a particular hood or from a central station for the entire system. Figure 4 shows a sketch of a central filtering system. Exhaust systems may be single or multiple units.

In supply air systems it is strongly recommended that A.E.C. filters be installed in a part of the system which is under pressure, Figure 5, to insure that any leakage in the clean part of the system will be outwards. The filter bank is located to give easy access for checking and changing filters. A plenum chamber, usually 3 to 4 ft. long in the direction of air flow and as large in cross section as the face area of the filter bank, is required upstream of the filters. Access to the dirty-air side is necessary only for servicing and changing.

Supply ventilation air uses are found primarily in industry requiring the highest degree of air cleaning, such as pharmaceutical manufacturing. An installation for supplying ventilation air in a leading pharmaceutical plant is shown in Figure 6. This system consists of forty 1,000 cu.ft./min. units for a total capacity of 40,000 cu.ft./min.

Prefilters are recommended only for economy according to dust concentration in air being filtered. A.E.C. filters should be reserved for filtering finer particles from the airstream.

Each installation includes a draft gauge to measure the pressure drop across the filter bank. The allowable pressure-drop limit established by the design engineer indicates when filters are to be changed. If filters are installed according to rated capacity, the initial pressure drop for the installation will be 1 in. of water. Generally filters are changed when the pressure drop has increased 1 in.; however, filters can be operated satisfactorily at higher pressure drops—up to 6 in. Usually the fan capacity of the system determines filter changes; filters should not be left in a system after resistance has resulted in a substantial decrease in air flow.

Tightness is the primary concern in all installations. The filters provide an almost complete barrier to the passage of all particles in the air stream, but one leak in the installation by-passing the filters could nullify the effectiveness of the installation. An all-welded casing of 18-gauge sheet steel is recommended as a simple, adequate means of holding the filters firmly in place. A positive seal of a tape which has excellent adhesive qualities, moisture resistance, and long life is applied carefully at the face of the filter bank. Filters with ¾-in. sponge rubber gaskets on one or both faces of the frame are available. The design for this type of installation usually requires a clamping device compressed against the gasket to provide a tight seal.

Process air uses generally require compressed air systems. Since the filter is designed for low-pressure systems, it is installed on the inlet side of compressors. A few special units have been used in pressure applications. Another use is providing sterile air to antibiotic fermentors.

Often the question is asked, "Will this filter remove smoke?" A DOP test based on 0.3 μ smoke particles was described above. The effectiveness of the filter medium on cigarette smoke, which ranges in size from 0.01 to 0.1μ, can be clearly shown with the "Smoke-stop" demonstrator which consists of two transparent funnels with the large ends separated by a sheet of filter paper. A cigarette in one end of the "Smoke-stop" is lighted and smoked from the other end. All smoke collects in the funnel. No visible smoke passes through the filter medium.

Economy

The cost of a filter installation depends primarily on the frequency with which filters have to be changed or, in other words, on the life of a set of filters. The life of filters varies, with much depending on the dirt conditions in the area in which the system operates and on the type of prefiltering. The initial cost of a system is not large. Once filters are properly installed, the only operating cost incurred until filters have to be changed is the slight additional cost for power to operate the fan. Experience indicates that filters will last, on an average, about 18 months. Annual operating costs for a 10,000 cu.ft./min. system generally run between \$55 and \$65/1,000 cu.ft./min.

A new high temperature filter similar in design to the filter described above has recently been developed by Arthur D. Little, Inc. The filter medium is an asbestos bearing glass paper pleated in the same manner as the A.E.C. filter and inserted in a metal frame. Corrugated aluminum separators are used instead of paper separators. The performance of both filters is comparable.

D. H. Northrup: These filters will withstand very humid conditions. A filter operated in an area where the moisture was rolling off the walls of the room did not fail. However, after a certain period of time the pleats will tend to buckle. We do not recommend using A.E.C. filters immediately downstream of air washers or spray dehumidifiers.

Anonymous: What is the effect of oil particles on A.E.C. filters?

D. H. Northrup: The A.E.C. filter stands up well against oil particles. The dioctyl phthlate smoke which we use in our DOP test is an oily smoke and has no effect on the filter.

D. A. Smith (Humble Oil & Refining Co., Baytown, Tex.): Would this filter be useful for removing the sulfuric acid mist which carries through Cottrell precipitators on hot air sulfuric acid concentrations?

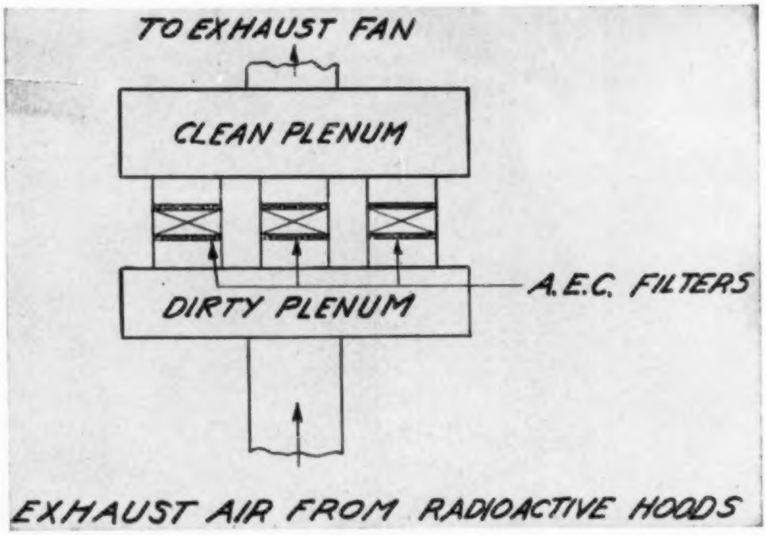


Fig. 4. Sketch of exhaust system.

Discussion

M. Bedrick (E. R. Squibb & Sons, New Brunswick, N. J.): Are A.E.C. filters used in place of or in conjunction with electrostatic filters?

D. H. Northrup: Electrostatic filters are frequently used as prefilters to A.E.C. filters. In other installations they are used in place of electrostatic filters.

Anonymous: How much pressure drop will the A.E.C. filter withstand?

D. H. Northrup: Although it is usually impractical to operate with as much static as 6, 8, or 10 in., the filters nevertheless have been tested to withstand such pressures.

Anonymous: What effect does moisture have on the A.E.C. filter? Do you have to predry the air before using these filters?

D. H. Northrup: Sulfuric acid tends to disintegrate the filters. At first it might be in such low concentration that there would be no breakdown of the filter. However, as it began to build up on the filter itself, a disintegration would gradually take effect. This difficulty could possibly be overcome with the new glass paper which I have previously referred to.

D. W. Correll (Kaiser Aluminum Co., Baton Rouge, La.): Why are prefilters used before the A.E.C. filter?

D. H. Northrup: Prefilters are used to remove the coarser dirt particles. In other words, the A.E.C. filter is a polishing filter and consequently should be used for re-

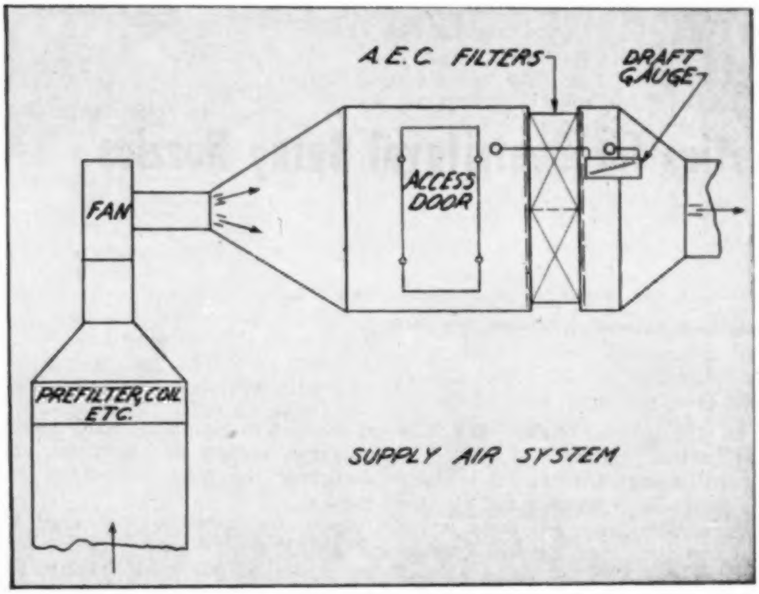


Fig. 5. Sketch of supply air system.

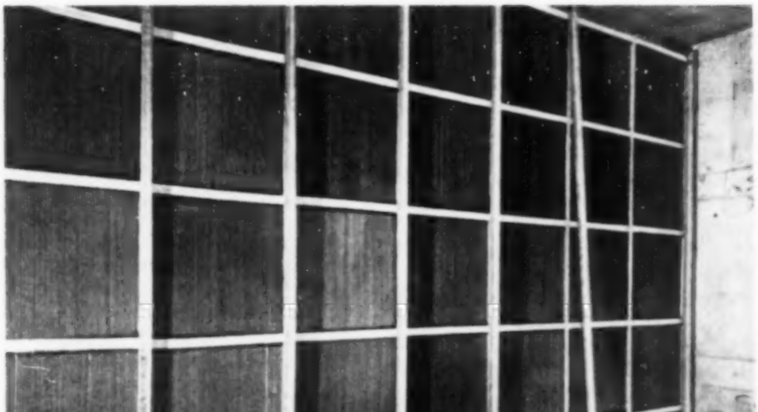


Fig. 6. 40,000 cu.ft./min. system in filling room of pharmaceutical plant.

moval of only fine particles. Removal of coarser particles can be accomplished more economically with various prefilters.

D. W. Correll: You mentioned the A.E.C. filter was effective against oil particles. How would this filter stand up against tar fumes?

D. H. Northrup: Tar fumes would have a tendency to plug the filter rapidly. The filter would remove tar fumes satisfactorily, but the life of the filter would be limited.

D. W. Correll: What temperatures will the A.E.C. filter withstand?

D. H. Northrup: A.E.C. filters can be operated under constant temperature up to 220° F., or occasionally up to 250° F. However, above that they will gradually break down. However, the new glass filter just developed is similar to the present A.E.C. filter in every respect as far as efficiency, design, and pressure drop are concerned. This new filter has an asbestos-bearing glass paper filter medium. Instead of a plywod frame, a metal frame is used; instead of paper separators, aluminum foil is used. This filter will withstand temperatures exceeding 500° F.

G. R. Eudaley, Jr. (The Texas Co., Port Arthur, Tex.): I noticed that in the examples presented of installations of greater than 1,000 cu.ft./min. capacity a battery of 1,000 cu.ft./min. units was used. Are higher capacities customarily achieved in this manner, or do you make individual units of more than 1,000 cu.ft./min. capacity?

D. H. Northrup: Large cu.ft./min. systems are, in general, built up with individual 1,000 cu.ft./min. cells, although any size unit up to 4 ft. square can be made. The 1,000 cu.ft./min. unit is the most practical size. It weighs approximately 45 lb. and is easy for one man to handle.

Presented at A.I.Ch.E. Biloxi meeting.

CORRECTION

In "The Separation of Gases by Means of Porous Membranes," Part II, authored by H. E. Huckins and Karl Kammermeyer ("C.E.P." June, 1953), an error occurs on page 295 in explaining Equation (19). It should be as follows:

where

$$A = \tfrac{1}{2}\left[(1-a)\frac{p}{P} + a\right]$$

$$B = -AC + a/2$$

$$C = -\tfrac{1}{2}\left[(1-a)\frac{p}{P} - 1\right]$$

As printed the minus sign was missing from before AC in $B =$ . . . and before ½ in $C =$ . . .

Liquid-Film Properties for Centrifugal Spray Nozzles

M. Doumas and R. Laster

General Foods Corporation, Hoboken, New Jersey

The process of fluid atomization is rapidly gaining importance in the chemical industry as well as in other technological advances. Spray drying, spray cooling, spray absorption and extraction are some examples where atomization plays an integral part of the operation. The commonly accepted performance measure of the atomizing step is the drop-size distribution resulting from the atomizer. Knowledge of this distribution permits calculations of the amount of surface generated and opens the possibility of further technical developments on the processes just mentioned.

Techniques commonly employed for the dispersion of liquids are two-fluid nozzles, centrifugal (spinning) discs and pressure nozzles.

The purpose of this study was to determine the velocities and film thicknesses of the liquid sheet issuing from centrifugal pressure nozzles. The bulk of the work reported covers a series of centrifugal nozzles obtained from Spraying Systems Co. under the trade name of Whirljet nozzles. Data and correlations were obtained using water.

Correlations were obtained that permit the computation of the liquid sheet velocities and film thickness from the knowledge of the physical dimensions of the spraying nozzles and the fluid pressure. These computations are broken down into calculations of the liquid flow rate, the spray angle, and the dimension of the air core at the center of the nozzle discharge orifice. The size of the air core was found to be dependent on the properties of the spray nozzle and independent of pressure.

Literature Review, General Considerations

Atomization essentially consists of two stages (a) the formation of filaments and (b) the filament disruption into droplets.

Lord Rayleigh (*5*) has shown that a liquid cylinder is unstable and that the slightest disturbance will cause severe distortions, with an eventual collapse into droplets.

The formation of filaments is accomplished by spreading a liquid out into a thin sheet. The sheet then draws up into filaments on its free edge (*3*). Although a great deal of work has been done on atomization (*2*), a limited amount of experimental work has been published dealing with the theory or the mechanism of the liquid sheet formation. A complete understanding of this mechanism can be achieved only by a flow analysis within the spray nozzle. Using centrifugal nozzles as a model both Vörös (*7*) and Novikov (*4*) present a mathematical analysis of the liquid flow.

Liquid under a hydrostatic head is forced through an opening, which is normally tangent to a whirl chamber. In this manner part of the pressure head is converted into a velocity head, causing a rotational velocity in the chamber. The remaining pressure head is utilized to increase the speed of the liquid circulation towards the center of the whirl chamber, maintaining a constant momentum, and to supply the velocity head for increased radial speed. As a result of the increased rotational and radial energy the pressure decreases towards the center in a hyperbolic fashion, resulting in atmospheric pressure at some point in the chamber itself. At that point an air core is formed which extends from the chamber through the outlet orifice into the outside air, and thus the liquid issues with an annular cross section, having horizonal velocity components due to the rotational energy and a vertical component due to the mass flow. The spray angle at which the liquid sheet issues out of the orifice is the resultant of the above velocity components. (*See* Fig. 1.)

Vörös (*7*) attempted to arrive at values for the air core by measuring the spray energy. He accomplished this by impinging a spray on a metal disc and measuring the force exerted in this manner.

Since the impact was obtained by droplets hitting the plate at many different angles and in varying amounts, the resultant computations are tedious and approximate. Based on his studies Vörös reports an increasing air-core diameter with increasing orifice size. Although his data on the effect of pressure on the air core size are limited, a slight pressure effect is indicated.

Novikov (*4*) presents a mathematical treatment of liquid flow in a centrifugal nozzle assuming that the viscosity of the liquid can be ignored. The following basic equations govern the fluid flow.

Conservation of momentum

$$Vr = V_o R \qquad (1)$$

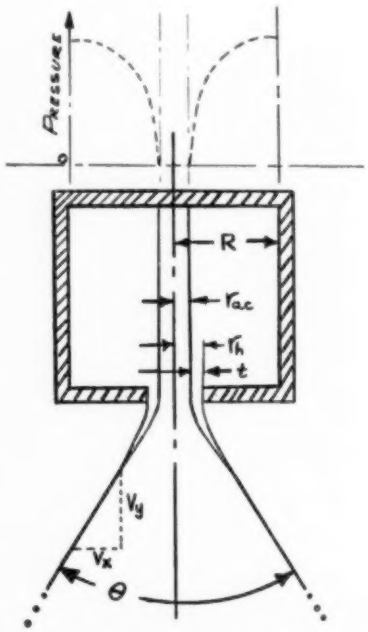


Fig. 1. Flow pattern in centrifugal spray nozzle.

For complete tabular data order document 4062 from A.D.I. Auxiliary Publications Photoduplication Service, Library of Congress, Washington 25, D. C., remitting $1.25 for microfilm (images 1 in. high on standard 25-mm. motion-picture film) or $1.25 for photoprints readable without optical aid.

Bernoulli's equation

$$\frac{P}{\rho} + \frac{V^2}{2g} + \frac{U^2}{2g} = H \tag{2}$$

Derived from (1) and (2)

$$\frac{dP}{dr} = \frac{\rho}{g}\frac{V^2}{r} \tag{3}$$

Continuity equation

$$\pi(R^2 - r^2_{ac})U_R = \pi r_o^2 V_o \tag{4}$$

Since the total number of unknowns in these equations is four (e.g., P, V, r_{ac} and U) and there are only three independent equations, Novikov found it necessary to use a hypothesis first postulated by G. N. Abramovich (*1*) according to which

$$\frac{\partial Q}{\partial r_{ac}} = 0 \tag{5}$$

Utilizing the above equations the following expressions can be derived.*

$$Q = K\pi r_h^2(2gH)^{1/2} \tag{6}$$

$$K = \alpha(1-\alpha)^{1/2}/(1-\alpha+\alpha^2A^2)^{1/2} \tag{7}$$

$$\alpha = 1 - \frac{r_{ac}^2}{r_h^2} \tag{8}$$

$$A = \frac{r_h R}{r_o^2} \tag{9}$$

$$A = \frac{1-\alpha}{\left(\frac{\alpha^3}{2}\right)^{1/2}} \tag{10}$$

It will be seen that Equation (9) expresses A in terms of the known physical nozzle dimensions. Knowing A, Equation (10) can be solved for α. Knowledge of A and α permits the evaluation of both the nozzle-discharge coefficient and the air-core dimensions.

It will be seen from Equations (7) through (10) that neither the coefficient of discharge nor the radius of the air core depends on the liquid feed pressure H.

Novikov proceeds to derive expressions for both the maximum and the minimum spray angle in terms of α. Mention is also made that the above conclusions are true above a certain minimum pressure when the liquid velocities are large and friction does not have a substantial effect.

The theoretical treatise presented by Novikov and outlined here was used as a basis for this study.

A physical evaluation of fluid flow in a centrifugal nozzle would require studies of flow-rate, spray-angle and air-core determinations.

Satisfactory methods for determining flow rate and spray angles are reported in the literature (*6*). A special technique had to be devised to determine air-core dimensions.

* See appendix for derivation.

A jet issuing from an orifice develops a reaction force equal and opposite to the product of mass and velocity. By determining the reaction force and the liquid flow a vertical velocity can be computed. Knowledge of the vertical velocity and the dimensions of the orifice permits calculations of both the film thickness, and the air-core dimensions.

Experimental Equipment and Procedures

Since the object of the study was to determine the effect of the nozzle dimensions on the behavior of the liquid going through, it was necessary to have a nozzle in which the inlet orifice, exit orifice, and chamber radius could be varied readily.

For this the Whirljet nozzles were used. A typical nozzle is shown in Figure 2. It can be seen that for a given body and chamber radius the exit orifice can be readily varied by replacing the head of the nozzle. Two chamber sizes were used, one corresponding to the nominal ¼-in. size nozzle and one corresponding to the ⅛-in. size. By combining various heads with the bodies a series of sixty-six different nozzles could be assembled. The physical measurements of these nozzles are shown in Table 1. A designation such as ⅛ A-3-5 represents a nozzle which is threaded for ⅛ size pipe, has a No. 3 body opening and a No. 5 head orifice. The body number always precedes the head number.

The nozzle dimensions were checked with a microscope with an accuracy of ± 0.004 of an in. Whenever any of the openings were found to be out of round, an average dimension is given in the table. However, the largest difference that was found between the maximum and minimum diameter was 7% and it generally restricted itself to the smaller bodies and heads.

The experimental work was directed towards measuring the following variables:

a. Flow rate of each nozzle at various pressures
b. Reaction of each nozzle at various pressures
c. Angle of spray
d. Photographic determination of the air core of various nozzles to give an estimate of the accuracy of the work.

The flow rate of each nozzle was determined by discharging the fluid into a container and then weighing it. Approximately 5-6 gal. were measured for each determination and a minimum of three different pressure determinations were made for each nozzle. Typical flow-rate data are shown in Figure 3. The pressures required were obtained from a triplex positive-displacement pump.

One object of the work was to determine the film thickness and velocity components of the liquid sheet at the exit of the nozzle. Since the reaction

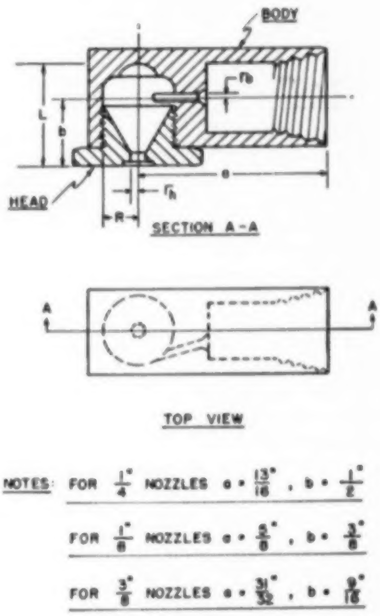


Fig. 2. Whirljet-type nozzle.

Table 1—Physical Properties of Nozzles

Type	Inlet Radius Inches r_o	Chamber Radius R in.	$R' = (R - r_o)$ in.	Axial Length in.
¼ A-2	0.0419	0.227	0.185	0.71
¼ A-3	0.0483	0.227	0.179	0.71
¼ A-4	0.06	0.227	0.167	0.71
¼ A-6	0.0752	0.227	0.152	0.71
¼ A-8	0.083	0.227	0.144	0.71
¼ A-10	0.093	0.227	0.134	0.71
⅜ A-6	0.0785	0.29	0.212	0.83
Monarch				
53 × 53	0.0315	0.219	0.1875	0.67
HEADS				
	r_h			
¼ A-2	0.039			
¼ A-3	0.0472			
¼ A-4	0.054			
¼ A-6	0.07			
¼ A-8	0.08			
¼ A-10	0.088			
¼ A-15	0.1085			
⅜ A-15	0.1075			
Monarch				
53 × 53	0.0295			
BODIES				
	r_o			
⅛ A-1	0.0285	0.165	0.136	0.57
⅛ A-2	0.0414	0.165	0.124	0.57
⅛ A-3	0.0502	0.165	0.115	0.57
⅛ A-5	0.0625	0.165	0.103	0.57
HEADS				
	r_h			
⅛ A-1	0.0285			
⅛ A-2	0.0395			
⅛ A-3	0.0462			
⅛ A-5	0.065			
⅛ A-8	0.076			
⅛ A-10	0.0875			

force from an escaping liquid jet is due to the product of the mass of liquid times its velocity in the direction of travel, it was felt that a reaction-force reading, combined with a knowledge of the flow rate at a given set of conditions, would provide a method of calculating the downward velocity V_y. From this the area occupied by the water and consequently the film thickness and air-core diameter could be calculated. Since a velocity gradient can exist in the film, V_y represents an average downward velocity. In addition, if a velocity gradient exists in the film, the calculated film thickness would of necessity also be an average film thickness and not a physically correct film thickness. Actually, if this gradient exists it can be shown that it would result in an apparent air-core diameter which is larger than the actual. The system used for the reaction measurements is shown in Figure 4. The nozzle rests on a wire support which is suspended from a triple-beam balance, and is connected to the piping by means of a flexible metal hose approximately ⅛ in. in diam. and 10 in. long. The hose had a tendency to curve slightly because of its own weight and that of the liquid inside. When the pressure was raised during a run, the hose tended to straighten itself out, thus affecting the reaction reading of the nozzle. To avoid this small error two readings were taken, one with the nozzle pointed up for which the hose effect would add to the reading, and one with the nozzle pointed down for which the hose would subtract from the reading. The average of these two values was then used. The difference in the two readings seldom exceeded 5%. Reaction-test data were taken for various pressures and typical curves are shown in Figure 5.

Since the combination of reaction- and flow-rate tests provide the downward velocity component V_y, it was necessary to measure the angle of the spray in order to determine the horizontal or tangential component V_x. Since the tangential component increases as the axis of the chamber is approached and since the direction or angle which a particle follows when it leaves the nozzle is a result of the components V_x and V_y, it follows that different paths should be followed by particles of liquid leaving from different radii of the film thickness. Specifically, particles leaving from the air-core surface have the maximum tangential velocity and therefore should produce the greatest angle. Particles leaving from the liquid next to the circumference of the head orifice should have the minimum tangential component and should result in the smallest angle. The over-all result will be an angle which represents the resultant of the vector sum of the velocities of all the particles. Upon the subsequent disruption of the liquid sheet into filaments and droplets, a rather wide spread takes place in the angle which is rather sharply defined by the liquid sheet. This is the result of undulation set up in the sheet due to friction with the air or other vibrations induced through the nozzle. In addition, since the drops formed are of various sizes, they will fall at different rates and travel unequal distances due to the fact that frictional drag with the air varies with the drop size. The over-all result, of course, will be an angle that is not sharply defined but which has a given spread. It was felt that the mean angle based on the volume of the liquid would most closely represent the average condition of the spray. To measure this angle, a series of 5/16-in. I.D. precision tubes were placed in a semicircle 10 in. away from the nozzle so that the center lines of the tubes were 3 degrees apart (*See Fig. 6*). The spray was then operated for a suitable length of time, the volume of liquid in the tubes was measured and the mean angle was calculated. Values for this angle are given in Table 2, while a typical distribution curve is given in Figure 7.

The pressure used during the spray-angle determination was 100 lb./sq.in. This has to be high enough to produce a large value of the Reynolds number in each nozzle so that the effect of liquid viscosity will become negligible, and the spray angle will attain its maximum or leveling-off value. Novikov and others have shown that, beyond a certain minimum pressure, the spray angle is constant. Attempts were made to check this constancy of the angle at higher pressures such as 1,000 lb./sq.in. but they

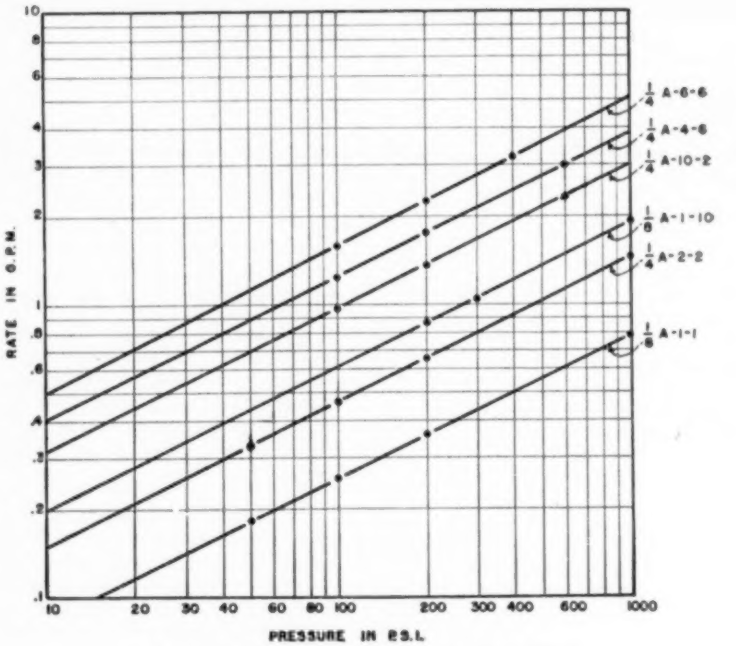


Fig. 3. Flow rate vs. pressure for typical Whirljet nozzles.

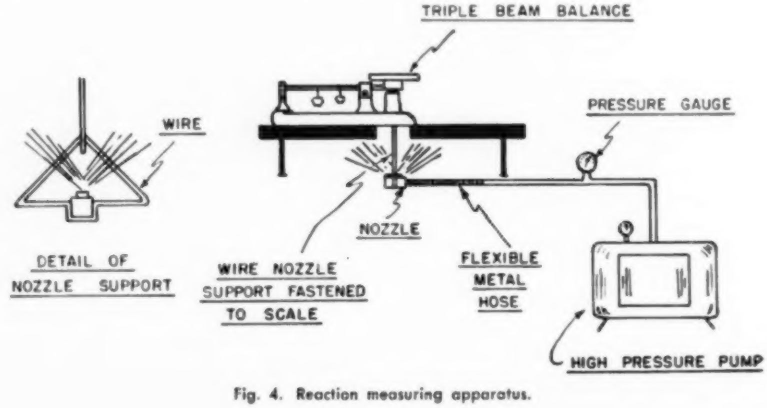


Fig. 4. Reaction measuring apparatus.

failed because of the compressing effect produced by the air that is dragged along the spray. This resulted in an obvious inward bending of the spray and erroneous angles.

In order to estimate the difference, if any, between the air-core diameter and film thickness calculated from the reaction test against the actual values, photographs were taken of the exit orifice during operation of the spray. To accomplish this a camera was placed behind a shield through which glass openings were provided for the camera and the lighting equipment. (*See* Fig. 8.) Photographs were taken during operation at exposures of 1/100 and 2/millionths of a second using a G.E. photo light. The high-speed photographs were used for checking the smoothness of the air core since at that speed any motion would be stopped. Any out-of-roundness or filaments there would not show in the lower speed photographs. As it turned out both photographs gave the same results with the inner surface appearing round, smooth, and of the same dimension on both. In addition, a photograph was taken without disturbing the setup when the nozzle was not operating and the exit orifice outline was clearly in focus. By measuring the photographs under the microscope and by knowing accurately the exit orifice, the air core was determined by simple proportion. However, it proved a tedious operation since under magnification the sharpness of the air core and orifice outlines diminished considerably. Figures 9, 10 and 11 show the nozzle when it was not operating and Figures 12, 13, 14 and 15 show the nozzles when spraying water at various pressures.

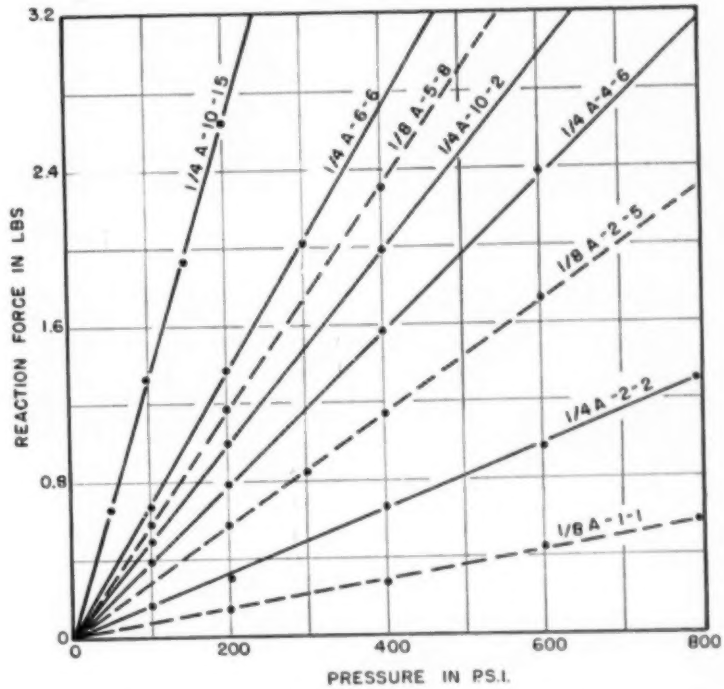


Fig. 5. Reaction force vs. pressure for typical Whirljet nozzles.

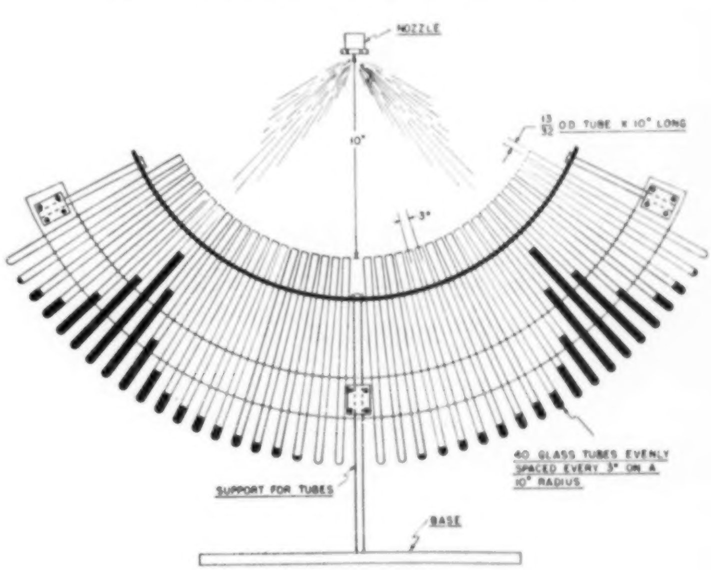


Fig. 6. Angle measuring apparatus.

Analysis and Results of Data

From data of flow rate vs. pressure it was found that the flow rate varies as the square root of the pressure (see Fig. 3).

$$Q = C_1 P^{1/2} \text{ cu.ft./sec.} \tag{11}$$

represents the equation of flow of a given nozzle. If the water leaves the nozzle with a downward velocity equal to V_y ft./sec. then the area occupied by the water will be

$$A = \frac{Q}{V_y} = \frac{C_1 P^{1/2}}{V_y} \text{ sq.ft.} \tag{12}$$

The reaction force F is equal to

$$F = MV_y \text{ lb.} \tag{13}$$

where M is the mass rate of liquid in slugs/sec. and from Equation (11) is equal to

$$M = C_2 P^{1/2} \text{ slugs/sec.} \tag{14}$$

where C_2 is a new constant

Substituting Equation (13) and (14) in Equation (12),

$$A = \frac{C_3 P}{F} \tag{15}$$

Since the reaction F is found to vary linearly with pressure (Fig. 5), it can be represented by the equation

$$F = SP \text{ lb.} \tag{16}$$

where S is the slope of the line. Substituting Equation (16) in Equation (15),

$$A = \frac{C_3}{S} = C = \text{constant} \tag{17}$$

Since the area occupied by the water does not vary with flow rates for a given nozzle, it follows that the film thickness and air core are also constant. Any increase in flow, therefore, takes place only through an increase in the downward velocity component V_y of the

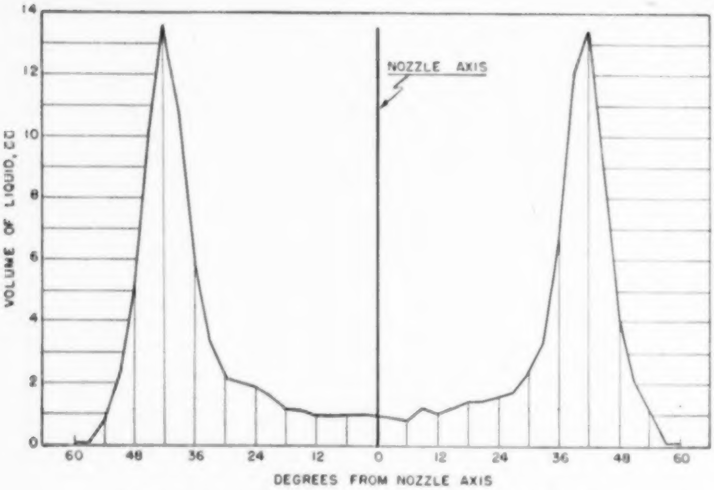


Fig. 7. Spray distribution pattern for ¼ A-2-4 at 100 lb./sq.in.

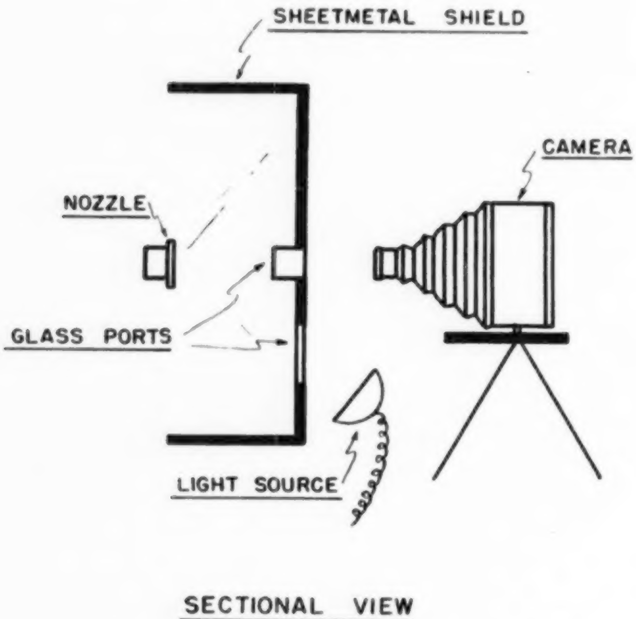


Fig. 8. Photographic apparatus for measuring nozzle air cores.

Table 2—Experimental Data

Nozzle	Rate at 200 lb./sq.in. gal./min.	Reaction at 200 lb./sq.in. lb.	At 100 lb./sq.in. Mean Angle Degrees
¼ A-2-2	0.65	0.30	65
2-3	0.82	0.36	72
2-6	1.14	0.43	84
2-8	1.25	0.46	84
2-15	1.64	0.58	96
¼ A-3-2	0.77	0.39	60
3-3	0.94	0.46	64
3-10	1.70	0.59	82
3-15	2.10	0.70	85
¼ A-4-2	0.92	0.52	52
4-3	1.17	0.61	61
4-6	1.77	0.80	71
4-8	2.04	0.91	74
4-15	2.83	1.15	83
¼ A-6-2	1.12	0.67	43
6-3	1.45	0.85	51
6-6	2.30	1.37	59
6-10	3.12	1.48	69
6-15	3.95	1.68	75
¼ A-8-2	1.26	0.85	37
8-3	1.60	1.10	45
8-8	3.12	1.77	59
8-15	4.80	2.26	70
¼ A-10-2	1.38	1.00	34
10-3	1.80	1.30	41
10-8	3.50	2.13	52
10-15	5.20	2.64	66
⅛ A-1-1	0.35	0.14	67
1-2	0.47	0.18	73
1-5	0.73	0.21	90
1-10	0.67	0.20	94
⅛ A-2-1	0.52	0.29	57
2-2	0.75	0.39	64
2-5	1.29	0.57	80
2-10	1.62	0.59	86
⅛ A-3-1	0.59	0.30	51
3-2	0.88	0.45	60
3-5	1.50	0.79	76
3-10	1.95	0.77	83
⅛ A-5-1	0.71	0.43	41
5-2	1.08	0.65	51
5-5	2.06	1.08	68
5-10	2.86	1.25	80
⅜ A-6-15	4.00	1.86	..
Monarch fig 631			
53 × 53	0.39	0.15	..

liquid. This justifies Novikov's assumption that $\partial Q/\partial r_{ac}$ is equal to zero.

For the experimental work the linear relationship between reaction and pressure was found to hold true for all nozzles tested through a series of pressures. It was therefore felt that measurement of the reaction at a given pressure and a knowledge of the rate at that pressure would be sufficient to determine the values of air core, film thickness, and V_y for a given nozzle. This procedure was used in testing most of the nozzles and the data are reported in Table 2 for a pressure of 200 lb./sq.in.

Equations used to calculate film properties for a given set of conditions are derived in the appendix and are as follows:

$$V_y = \frac{F}{0.00432q} \text{ ft./sec.} \qquad (18)$$

$$r_{ac} = \left(r_h^2 - \frac{0.00044q^2}{F} \right)^{1/2} \text{ in.} \qquad (19)$$

where

F = reaction force in pounds at pressure P (in this case 200 lb./sq.in.)

q = rate in gallons per minute at pressure P (in this case 200 lb./sq.in.)

r_h = exit radius in inches

r_{ac} = air core radius in inches

Calculated values of the air core are shown in Table 3 together with values of the coefficient of discharge. The latter is defined by K in Equation (6) as the actual rate divided by the maximum rate which would occur if the exit orifice was flowing full under the total available head at the inlet to the nozzle.

The coefficient of discharge K was

FIG. 9 – $\frac{1}{4}$ A-3-2

FIG. 10 – $\frac{1}{8}$ A-3-5

FIG. 11 – $\frac{1}{4}$ A-4-10

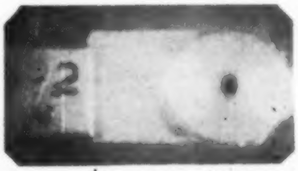


FIG. 12 – $\frac{1}{4}$ A-3-2 @ 200 P.S.I.

FIG. 13 – $\frac{1}{8}$ A-3-5 @ 200 P.S.I.

FIG. 14 – $\frac{1}{4}$ A-4-10 @ 200 P.S.I.

FIG. 15 – $\frac{1}{4}$ A-4-10 @ 500 P.S.I.

Fig. 9-15. Photographs of air cores of typical centrifugal nozzles.

correlated against the parameter A' in Figure 16, where A' is equal to

$$A' = \left(\frac{r_h R}{r_o^2}\right)\left(\frac{r_h}{R'}\right)^{1/2}$$

The value A' is actually Novikov's parameter A modified by $(r_h/R')^{1/2}$. This is a purely empirical modification without any direct theoretical support. The authors believe that this modification is necessary due to the effects of frictional drag on the nozzle surfaces and also between various liquid layers. Thus, the ratio (r_h/R') is an index of the maximum radial distance which the liquid has to travel, and this distance affects the conversion of the static pressure head into kinetic rotational head. By increasing this ratio the radial distance becomes shorter, resulting in less friction and a closer approximation to the theoretical rotational velocity. This results in less flow through the nozzle since less energy is available for increasing the axial velocity component.

Investigation of the effect of length on nozzle performance shows that higher rates are obtained with longer lengths, but the effect is small and within the error of the experiments when the ratio $(2R/L)$ varies between 0.6 to 1.5 in. The maximum deviation between a calculated coefficient of discharge using A' and an experimental one for the ¼-in. nozzles is 7% with

Table 3.

Nozzle	A	A'	Discharge Coefficient K: Experimental	Discharge Coefficient K: Calculated	Air-Core Radius r_{ao}: Experimental	Air-Core Radius r_{ao}: Calculated	Experimental Film Thickness t in.
¼ A-2-2	5.04	2.30	0.257	0.264	0.030	0.031	0.0090
2-3	6.06	3.14	0.220	0.208	0.038	0.039	0.0095
2-6	9.02	5.55	0.139	0.135	0.060	0.061	0.0100
2-15	14.00	10.70	0.083	0.076	0.097	0.098	0.0117
¼ A-3-2	3.79	1.77	0.302	0.315	0.029	0.030	0.0097
3-3	4.58	2.36	0.252	0.260	0.037	0.038	0.0100
3-10	8.55	5.96	0.132	0.129	0.075	0.076	0.0133
3-15	10.55	8.20	0.106	0.098	0.095	0.095	0.0135
¼ A-4-2	2.45	1.19	0.361	0.390	0.028	0.028	0.0105
4-3	2.97	1.58	0.313	0.330	0.035	0.035	0.0120
4-6	4.41	2.85	0.215	0.220	0.056	0.056	0.0137
4-8	5.04	3.50	0.190	0.190	0.066	0.066	0.0137
4-15	6.84	5.50	0.143	0.136	0.092	0.092	0.0165
¼ A-6-2	1.56	0.79	0.440	0.480	0.026	0.026	0.0127
6-3	1.88	1.04	0.390	0.420	0.034	0.033	0.0134
6-6	2.80	1.90	0.280	0.300	0.057	0.053	0.0128
6-10	3.52	2.68	0.241	0.237	0.070	0.069	0.0184
6-15	4.33	3.67	0.200	0.185	0.088	0.086	0.0205
¼ A-8-2	1.29	0.67	0.494	0.520	0.026	0.025	0.0126
8-3	1.56	0.89	0.429	0.455	0.035	0.032	0.0125
8-8	2.64	1.97	0.290	0.293	0.063	0.060	0.0169
8-15	3.58	3.10	0.242	0.210	0.086	0.085	0.0230
¼ A-10-2	1.02	0.55	0.542	0.580	0.026	0.024	0.0129
10-3	1.23	0.73	0.482	0.510	0.034	0.030	0.0136
10-8	2.10	1.62	0.325	0.330	0.062	0.057	0.0178
10-15	2.84	2.55	0.263	0.245	0.086	0.081	0.0230
⅛ A-1-1	5.78	2.64	0.257	0.240	0.020	0.023	0.0083
1-2	8.00	4.30	0.181	0.163	0.032	0.034	0.0078
1-5	13.20	9.10	0.103	0.090	0.056	0.059	0.0092
1-10	17.70	14.20	0.068	0.058	0.078	0.080	0.0095
⅛ A-2-1	2.74	1.31	0.383	0.375	0.020	0.021	0.0085
2-2	3.80	2.14	0.288	0.277	0.031	0.031	0.0080
2-5	6.25	4.52	0.183	0.157	0.055	0.055	0.0103
2-10	7.93	6.65	0.126	0.118	0.076	0.076	0.0118
⅛ A-3-1	1.87	0.94	0.434	0.450	0.017	0.018	0.0111
3-2	2.60	1.52	0.340	0.345	0.028	0.028	0.0111
3-5	4.27	3.20	0.211	0.205	0.053	0.052	0.0122
3-10	5.42	4.71	0.152	0.153	0.074	0.072	0.0133
⅛ A-5-1	1.20	0.63	0.521	0.560	0.017	0.017	0.0110
5-2	1.66	1.03	0.415	0.420	0.028	0.026	0.0111
5-5	2.74	2.16	0.290	0.278	0.052	0.049	0.0138
5-10	3.48	3.20	0.223	0.207	0.070	0.069	0.0173
⅜ A-6-15	5.06	3.60	0.206	0.187	0.088	0.088	0.0195
Monarch 53 × 53	6.5	2.24	0.267	0.270	0.021	0.025	0.0088

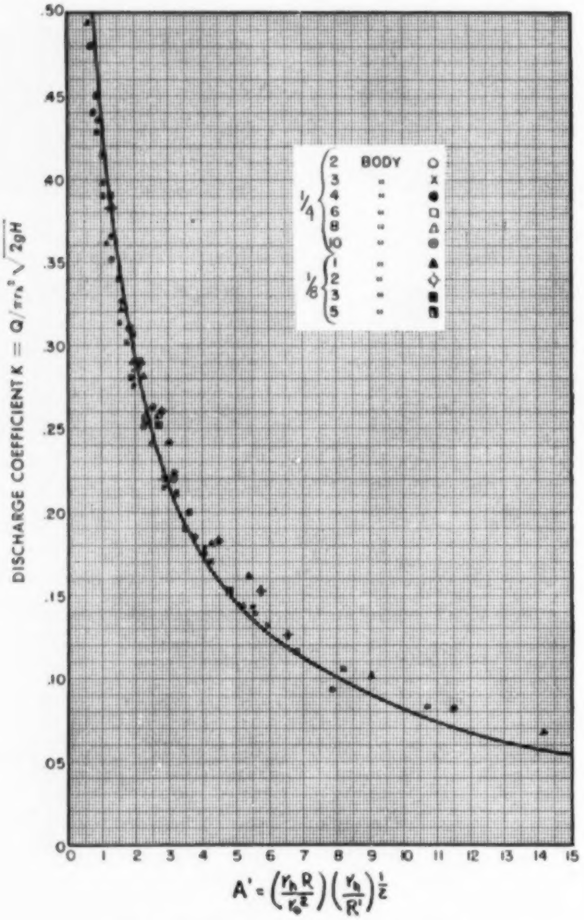


Fig. 16. Discharge coefficient vs. parameter A'.

most of the values showing much closer agreement. The difference in values for the ⅛-in. size reaches a maximum of 15% for the No. 1 body, but here small errors in the measurement of the inlet and outlet orifices would make a large difference in the calculated value of A'.

The procedure for calculating the coefficient of discharge consists of determining first the value of A' from the nozzle dimensions and finding a' from the relationship

$$A' = \frac{1-a'}{\left[\frac{(a')^3}{2}\right]^{1/2}} \tag{10 (a)}$$

a' can be substituted in the equation for K where

$$K = \frac{a'(1-a')^{1/2}}{[1-a'+(a')^2(A')^2]^{1/2}} \tag{7}$$

The air core is calculated by using Novikov's parameter A, finding a by Equation (10) and substituting in Equation (8) where

$$r_{ac} = r_h(1-a)^{1/2} \tag{21}$$

The calculated air-core values when compared to the experimental ones show a maximum deviation of 10% with the average deviation being much less than that or about 2-3%.

The air core as determined from the photographs exceeds the value obtained from the reaction data with a maximum difference of 7%. This comparison is illustrated in Table 4. However, the accuracy of measurement of the negatives was not too great so that it is difficult to evaluate the significance of the difference.

Table 4.—Comparison of Air-Core Radius by Reaction Method and by Photographic Method

Nozzle	Reaction Air-Core Radius in.	Calculated Air Core Radius in.	Photographic Air-Core Radius in.
¼ A-3-2	0.029	0.030	0.030
¼ A-3-15	0.095	0.095	0.102
¼ A-4-10	0.073	0.073	0.076
⅛ A-3-5	0.053	0.052	0.056
⅛ A-5-10	0.070	0.069	0.076

The spray angle was correlated against A' (*See* Fig. 17) and can be represented by the equation

$$\theta_m = 43.5 \log. 14A' \tag{22}$$

As pointed out Equation (*22*) represents the mean of a distribution of angles having a maximum value at the air core and a minimum value adjacent to the orifice wall.

To obtain a measure of nozzle efficiency, the energy content of the liquid sheet at the air core was compared to the hydrostatic head in front of the nozzle. At this point the sheet contains only rotational and vertical velocity heads since the pressure head has been converted to kinetic energy. Using the maximum angles obtained experimentally to compute the rotational velocities at the air core, nozzle efficiencies of 80-120% were obtained. The accuracy of these calculations, however, is poor because of low precision on the determinations of the maximum angles.

Summary

In the study of centrifugal spray nozzles a correlation was obtained between the physical dimensions of the nozzle and the properties of the liquid sheet issuing from the nozzle. Equations are presented from which the coefficient of discharge, the liquid film thickness and its velocity components, the air core and spray angle can be calculated.

The procedure for doing this is illustrated in the following examples:

Sample Calculations

PROBLEM 1

Given a nozzle with the following characteristics:

Radius of inlet orifice = r_o = 0.06 in.
Chamber radius = R = 0.227 in.
Radius of the head = r_h = 0.08 in.

For 200 lb./sq.in. calculate the following:

(a) discharge in gal./min.
(b) mean spray angle
(c) air-core radius
(d) film thickness
(e) total velocity of fluid at exit orifice

a. DISCHARGE COEFFICIENT

First calculate A' from Equation (20)

$$A' = \left(\frac{r_h R}{r_o^2}\right)\left(\frac{r_h}{R'}\right)^{1/2}$$

$$= \left(\frac{0.08 \times 0.227}{0.06^2}\right)\left(\frac{0.08}{0.167}\right)^{1/2} = 3.5$$

Calculate a' from Equation (10) or Figure 18.

$$\frac{(A')^2}{2}(a')^3 - (a')^2 + 2a' - 1 = 0$$

$$\frac{3.5^2}{2}(a')^3 - (a')^2 + 2a' - 1 = 0$$

from which a' = 0.39

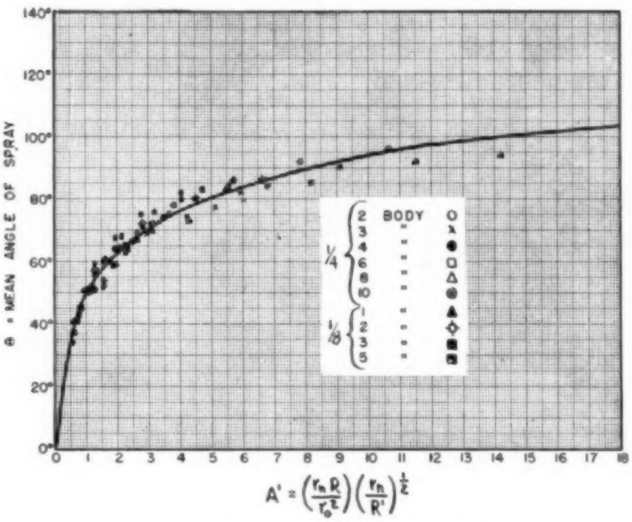


Fig. 17. Mean spray angle vs. parameter A'.

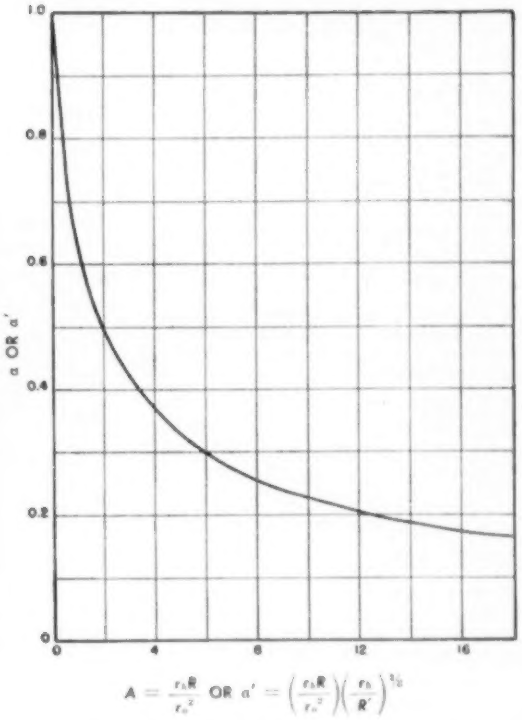


Fig. 18. Parameter A or A' vs. parameter a or a'.

Substitute the values of A' and a' in the equation for the coefficient of discharge.

$$K = \frac{a'(1 - a')^{1/2}}{[1 - a' + (a')^2(A')^2]^{1/2}}$$

$$= \frac{0.39(1 - 0.39)^{1/2}}{(1 - 0.39 + 0.152 \times 12.2)^{1/2}} = 0.194$$

Calculate the flow Q from Equation (6)

$$Q = K\pi r_h^2(2gH)^{1/2}$$

$$= 0.194 \times \frac{\pi\, 0.08^2}{144}(64.4 \times 462)^{1/2}$$

$$= 0.00465 \text{ cu.ft./sec.}$$

$$= 2.12 \text{ gal./min.}$$

b. MEAN SPRAY ANGLE

$$\theta_m = 43.5 \log 14\, A'$$

$$\therefore\ \theta_m = 43.5 \log 14 \times 3.5 = 74° \qquad (22)$$

c. AIR-CORE RADIUS

$$r_{ac} = r_h(1 - a)^{1/2}$$

$$A = \frac{r_h R}{r_o^2} = \frac{0.08 \times 0.227}{0.06^2} = 5.05 \qquad (21)$$

From Fig. (18) $a = 0.334$

$$\therefore\ r_{ac} = 0.08(1 - 0.334)^{1/2} = 0.0652 \text{ in.}$$

d. FILM THICKNESS

$$t = r_h - r_{ac} = 0.08 - 0.0652 = 0.0148 \text{ in.}$$

e. TOTAL VELOCITY OF PARTICLES

$$V_y = \frac{\text{Volume of flow}}{\text{Area of liquid at the head}}$$

$$= \frac{0.00465}{0.00014 - 0.0000928} = \frac{0.00465}{0.000046}$$

$$= 101 \text{ ft./sec.}$$

$$V_z = V_y \tan\frac{\theta_m}{2}$$

$$V_z = 101 \tan. 37° = 76 \text{ ft./sec.}$$

The resultant velocity V is

$$V = (V_y^2 + V_z^2)^{1/2} = (101^2 + 76^2)^{1/2}$$

$$= 127 \text{ ft./sec.}$$

PROBLEM 2

Determine the dimensions of a nozzle so that it will have the following characteristics at 400 lb./sq.in.:

(a) Mean spray angle = 69°
(b) Discharge rate = 4.42 gal./min. = 0.00984 cu.ft./sec.
(c) Film thickness = 0.018 in.

From Equation (22)

$$\theta_m = 43.5 \log 14A'$$
$$69° = 43.5 \log 14A'$$
$$A' = 2.75$$

From Figure 16 for $A' = 2.75$, $K = 0.231$

From Equation (6) there is

$$Q = K\left(\frac{\pi r_h^2}{144}\right)(2gH)^{1/2} \text{ or } r_h = \left(\frac{144Q}{K\pi(2gH)^{1/2}}\right)^{1/2}$$

$$r_h = \left(\frac{144 \times 0.00984}{0.231 \times 3.14 \times (64.4 \times 924)^{1/2}}\right)^{1/2}$$

or

$$r_h = 0.089 \text{ in.}$$

Since:

$$A' = \left(\frac{r_h R}{r_o^2}\right)\left(\frac{r_h}{R'}\right)^{1/2}$$

By substitution,

$$2.75 = \left(\frac{0.089 \times R}{r_o^2}\right)\left(\frac{.089}{R - r_o}\right)^{1/2}$$

If a definite film thickness is not required, then by assuming a value for either R or r_o the equation can be solved for the other variable, thus completely specifying the nozzle to give the required discharge rate and spray angle.

When the film thickness is specified, however, the exact relationship must be obtained between R and r_o which will result in the required film thickness or:

$$r_{ac} = r_h - t = 0.089 - 0.0185 = 0.0705 \text{ in.}$$

$$a = 1 - \left(\frac{r_{ac}}{r_h}\right)^2 \text{ from Equation (8)}$$

$$= 1 - \left(\frac{0.0705}{0.089}\right)^2 = 0.37$$

From Figure 18 when $a = 0.37$, $A = 3.95$

$$\text{Since } A = \frac{r_h R}{r_o^2}$$

this value can be substituted in A'

or

$$2.75 = 3.95 \left(\frac{0.089}{R - r_o} \right)^{1/2}$$

from which $R - r_o = 0.184$ (a)

Also from $A = \frac{r_h R}{r_o^2}$

$$\frac{R}{r_o^2} = \frac{3.95}{.089} = 44.3 \quad (b)$$

Solving Equations (a) and (b) simultaneously,

$R = 0.261$
$r_o = 0.077$ in.

which together with $r_h = 0.089$ in. completely specify the nozzle. If a film thickness of 0.0150 in. was required, r_h would remain the same but R and r_o would be

$R = 0.467$ in.
$r_o = 0.0855$ in.

Notation

$A = \frac{\pi r_h R}{a}$ which for circular opening is $= \frac{r_h R}{r_o^2}$

$A' = \left(\frac{\pi r_t R}{a}\right)\left(\frac{r_h}{R'}\right)^{1/2}$ which for circular opening is $= \left(\frac{r_h R}{r_o^2}\right)\left(\frac{r_h}{R'}\right)^{1/2}$

a = area of inlet openings
F = reaction force
g = gravitational constant
H = total head of fluid
K = nozzle discharge coefficient
L = length of nozzle chamber
M = mass of liquid
P = pressure of liquid in pounds per unit area
Q = flow rate
R = chamber radius
$R' = R - r_o$
r_{ac} = radius of air core
r_h = radius of exit orifice
r_o = radius of inlet orifice
r = radius at any point
t = film thickness
U = vertical velocity component at any point
V = tangential velocity component at any point
V_o = inlet velocity component
V_x = horizontal velocity component
V_y = vertical velocity component
θ = spray angle
θ_{max} = outside spray angle
θ_m = mean spray angle
θ_{min} = minimum spray angle
ρ = density of fluid
$\alpha = 1 - \frac{r_{ac}^2}{r_h^2}$

Literature Cited

1. Abramovich, G. N., "Industrial Aerodynamics" (Russian), TSAGI, p. 18 (1944).
2. De Juhasz, K. J., and W. E. Meyer, "Sprays," Texas Co. refining dept. (August, 1948).
3. Kleinschmidt, R. V., "Chemical Engineers' Handbook," J. J. Perry, 2nd ed., McGraw-Hill, New York.
4. Novikov, I. I., *J. Technical Physics* (Russian), XVIII, No. 3, p. 345 (1948).
5. Rayleigh, "Theory of Sound," Dover publication, *Proc. London Math. Soc.*, **10**, 4 (1879).
6. Tate, R. W., and W. R. Marshall, Jr., *Chem. Eng. Progress*, **49**, No. 4, 169 (1953); No. 5, 226.
7. Vörös, Imre, Doctor's Thesis, Royal Hungarian University of Engineering, Budapest, Springer Press, Budapest (1935).

Appendix

Derivation of equations governing fluid flow in a centrifugal nozzle

Basic equations:

$V_o R = Vr$ Conservation of Momentum (1)

$$\frac{P}{\rho} + \frac{V^2}{2g} + \frac{U^2}{2g} = H \quad \text{Bernoulli's Equation} \quad (2)$$

$$\frac{dP}{dr} = \frac{\rho}{g}\frac{V^2}{r} \quad \text{Derived from (1) and (2)} \quad (3)$$

$$\pi(R^2 - r_{ac}^2)U_R = \pi r_o^2 V_o \quad \text{Continuity Equation} \quad (4)$$

$$\frac{\partial Q}{\partial r_{ac}} = 0 \quad \text{Assumption} \quad (5)$$

Substituting (1) into (3) one obtains,

$$\frac{dP}{dr} = \frac{\rho}{g} V_o^2 R^2 r^{-3}$$

Integrating:

$$P = -\frac{1}{2}\frac{\rho}{g} V_o^2 R^2 r^{-2} + C$$

@ $r = r_{ac}$, $P = 0$ from which $C = \frac{1}{2}\frac{\rho}{g}\frac{R^2}{r_{ac}^2}V_o^2$

$$\therefore P = \frac{1}{2}\frac{P}{g} V_o^2 R^2 \left(\frac{1}{r_{ac}^2} - \frac{1}{r_h^2}\right)$$

@ the head where $r = r_h$ (6)

from Equation (1):

$$V_h^2 = V_o^2 \frac{R^2}{r_h^2};\ V_o = \frac{Q}{\pi r_o^2}$$

$$\therefore V_h^2 = \frac{Q^2 R^2}{\pi r_o^4 r_h^2}$$

$$Q = \pi(r_h^2 - r_{ac}^2)u_h$$

or

$$u_h^2 = \frac{Q^2}{\pi^2 (r_h^2 - r_{ac}^2)^2}$$

Substituting (6), (7) and (8) in (2) and factoring

$$H = \frac{Q^2}{2\pi^2 g r_h^4}\left[\frac{R^2 r_h^4}{r_o^4}\left(\frac{1}{r_{ac}^2} - \frac{1}{r_h^2}\right) + \frac{R^2 r_h^2}{r_o^4} + \frac{r_h^4}{(r_h^2 - r_{ac}^2)^2}\right]$$

$$\therefore Q = \pi r_h^2 \sqrt{2gH}\sqrt{\frac{1}{\frac{R^2 r_h^4}{r_o^4 r_{ac}^2} + \frac{r_h^4}{(r_h^2 - r_{ac}^2)^2}}} \quad (9)$$

Let

$$\alpha = 1 - \frac{r_{ac}^2}{r_h^2} \text{ and } A = \frac{r_h R}{r_o^2}$$

Then:

$$Q = \pi r_h^2 \sqrt{2gH}\frac{\alpha\sqrt{1-\alpha}}{\sqrt{1 - \alpha + \alpha^2 A^2}} \quad (10)$$

where the discharge coefficient is:

$$K = \frac{\alpha\sqrt{1-\alpha}}{\sqrt{1 - \alpha + \alpha^2 A^2}} \quad (11)$$

From Equation (9)

$$\frac{\partial Q}{\partial r_{ac}} = -\frac{1}{2}\pi r_h^2\sqrt{2gH}\,[A^2 r_h^2 r_{ac}^{-2} + r_h^4(r_h^2 - r_{ac}^2)^{-2}]^{-3/2} \times [-2A^2 r_h^2 r_{ac}^{-3} - 2r_h^4 (r_h^2 - r_{ac}^2)^{-3}(-2r_{ac})]$$

If $\frac{\partial Q}{\partial r_{ac}} = 0$ by assumption, then

$$\frac{A^2 r_h^2}{r_{ac}^3} = \frac{2 r_{ac} r_h^4}{(r_h^2 - r_{ac}^2)^3}$$

Substituting for α,

$$A^2 = 2(1-\alpha)^2\frac{1}{\alpha^3}$$

$$A = \frac{1-\alpha}{\sqrt{\frac{\alpha^3}{2}}} \quad (12)$$

If the inlet orifice is not round, or if there is more than one inlet, the definition of A in the above equations is changed to the following:

$$A = \frac{\pi r_h R}{a} \quad (13)$$

where a is equal to the total cross-sectional area of all the inlet orifices.

(1) AIR-CORE CALCULATION FROM EXPERIMENTAL DATA

Let

q = flow rate in gal./min. (1)
$q_1 = 0.00223q$ cu.ft./sec. (2)
$q_2 = 3.85q$ cu.in./sec. (3)
$q_3 = 0.00432q$ slugs/sec. (4)

The area occupied by the escaping liquid, A, is equal to the total volume divided by the downward velocity or

$$A = \frac{0.00223q}{V_y} \text{ sq.ft.} \quad (5)$$

The reaction force F is equal to:

$$F = MV_y \text{ lb.} \quad (6)$$

where M is the mass of liquid in slugs/sec. Substituting V_y from Equation (6) into (5) and the value of M from Equation (4),

$$A = \frac{0.00223\,q}{\frac{F}{0.00432\,q}} = \frac{0.00000962\,q^2}{F} \text{ sq.ft.}$$

$$= \frac{0.00138\,q^2}{F} \text{ sq.in.} \quad (7)$$

$$\text{Air-core area} = \pi r_h^2 - \frac{0.00138\,q^2}{F} \text{ sq.in.} \quad (8)$$

Therefore, the air core radius r_{ac} is

$$r_{ac} = \left(r_h^2 - \frac{0.00044\,q^2}{F}\right)^{1/2} \text{ in.} \quad (9)$$

Presented at A.I.Ch.E. Forty-fifth annual meeting, Cleveland, Ohio.

This paper describes the first successful commercial-scale roasting in North America of zinc sulfide flotation concentrates in a FluoSolids reactor to produce a zinc oxide calcine for electrolytic leaching and at the same time to produce sulfur dioxide gas for a contact sulfuric acid plant. The operation is also a "first" in respect to size, the reactor having almost two and one-half times the hearth area of any previously built for use on other ores. Attention is given particularly to design problems brought about by the close thermodynamic balance of the reactions and the lack of commercial experience with this type operation.

Part of the paper tells about the events, thinking, thermodynamic calculations, and experimental work behind the development. Another part explains the easy-handling wet-feed system adopted and the modern centralized instrumentation, which adds much to plant control. Sufficient operating data have been included to illustrate typical results obtained by the plant as a whole.

FluoSolids Roasting of Zinc Concentrates for Contact Acid

T. T. Anderson

T. T. Anderson, a graduate chemical engineer from the University of British Columbia in 1942, has been assistant chief engineer in charge of chemical engineering, Aluminum Company of Canada, Limited, Montreal, Que., since 1952. Associated early in his career with paper companies, he later joined the Aluminum Company at Arvida, Que., where he spent three years in Bayer ore plant operations, two years in Bayer and electrolyte plant development. Subsequently he held the job of assistant superintendent of operations in the fluoride group of plants and in 1949 was transferred to Montreal to the general engineering department. In addition to holding membership in the A.I.Ch.E., Mr. Anderson is a member of the Engineering Institute of Canada and the Professional Engineers of Quebec.

R. Bolduc

Since 1948 Raymond Bolduc has been associated with the Aluminum Company of Canada first as assistant supervisor in ore plant and fluoride department and since 1951 at work on the design, construction, and operations of the sulfuric acid plant No. 2, which he now supervises. A native of Asbestos, Que., Mr. Bolduc received degrees from the University of Montreal and Laval University. Previous to his affiliation with Aluminum Company of Canada, Mr. Bolduc was with the French Supply Council in Washington, D. C., as purchasing agent.

A. General Situation

It will be remembered that in late 1950 there was a sudden world shortage of sulfur. Expansion of its use in many fields plus lack of new elemental sources had caused raw sulfur stockpiles to shrink to dangerous levels. Accordingly the United States Government clamped an embargo on all further sales of sulfur to new customers, and in addition reduced supplies to established consumers.

B. Alcan's Situation

At this time the Aluminum Company of Canada Limited had decided to proceed with expansion in the East and with the now well-known Kitimat project in British Columbia. This planned expansion of primary aluminum capacity carried with it the secondary requirement of expanded electrolyte supplies, particularly aluminum fluoride and cryolite. Both these materials, if manufactured synthetically, require hydrogen fluoride which comes from the reaction of sulfuric acid on fluorspar. Alcan was producing only sufficient sulfuric acid to supply its pre-expansion operating requirements, and had no spare capacity. To ensure adequate supplies of electrolyte, Alcan turned to other sources of sulfur supply.

C. Alcan's Most Probable Sources of Sulfur

Pyrite or zinc concentrates were the alternative sources of sulfur available, particularly as the new acid plant would be located at Arvida, 150 miles north of Quebec City, Quebec. Electrolyte producing capacity had previously been developed there.

Alcan finally signed a contract to roast zinc sulfide concentrates for the American Zinc Co. of Illinois. These concentrates were in general to come from northern Quebec areas and the roasted product was to be shipped to the Monsanto, Ill., plant of the American Zinc Co., near East St. Louis.

Process Adopted for Making Acid

DESIRE FOR SIMPLICITY

Having made the choice to roast zinc concentrates as a means of increasing sulfuric acid production, Alcan decided that in view of its general lack of experience in this particular operation, every possible simplification was desirable.

Roasting of zinc concentrates requires close control. There is a much greater danger of fusion with zinc concentrates than with pyrite, the melting points of ZnS and FeS_2 being respectively 1020° C. and 1193° C. Lead and other impurities in the concentrates further complicate the problem.

A SUITABLE ROASTER

Could a Dorrco FluoSolids roaster make a good product for an electrolytic zinc refinery and gas suitable for a contact plant?

In answer to this question it should be stated that this type of roaster appealed as being a particularly suitable roaster if it could be made to operate on zinc concentrates, and if the gas produced was suitable for use in a contact plant. At that time there were no roasters of this type supplying gas to contact plants and this is probably still true today as regards North America. Such roasters were operating well with pyritic gold ores, but at the time had not been applied to the production of sulfur dioxide, although many jobs were apparently under consideration at pulp and paper plants. If Alcan were to adopt what appeared to be the most modern roasting technique, certain questions remained to be answered before the machine could be considered for roasting zinc concentrates commercially. Some of these were:

(a) Could the concentrates be successfully fed as a wet slurry thereby facilitating the feeding problem? This method had become the established method for feeding pyrite to such roasters.

(b) What waste heat recovery would be available per pound of contained sulfur, compared with other roasters?

(c) Could sulfide sulfur (ZnS) in the roaster product be held low enough to make the calcine suitable for electrolytic refining?

(d) Could sulfate sulfur ($ZnSO_4$) in the roasted product be held reasonably low?

(e) What size of roaster (or roasters) should be used, keeping in mind uniformity of product and continuity of plant operation?

(f) Would the operation be sufficiently uniform to give the desired close control, avoid fusion and formation of zinc ferrite?

(g) Would the gas strength from the roaster be adequate for a contact acid plant?

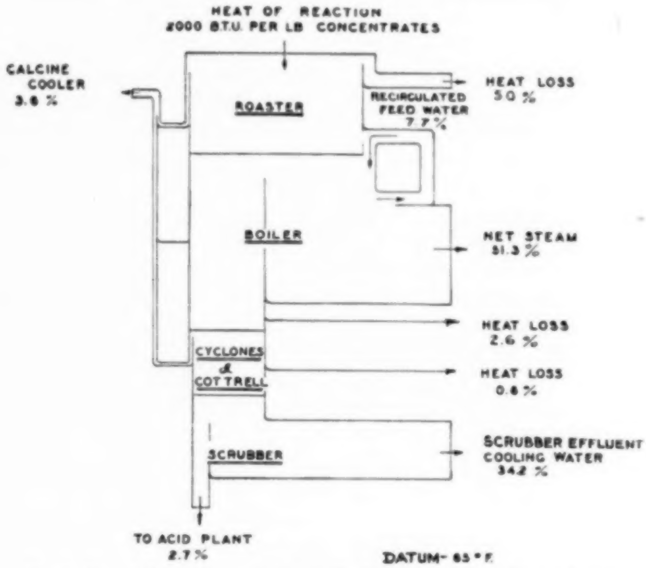


Fig. 1. Heat balance diagram—Dorrco FluoSolids roaster handling 120 tons per day zinc concentrates.

THEORETICAL CALCULATIONS

In order to answer some of these questions heat-balance calculations were made for a hypothetical reactor handling 120 tons (dry, short) of zinc concentrates/day containing 32% sulfur. The concentrates were assumed to be fed as an 80% solids slurry into the reactor; the gas was assumed to emerge from the reactor at 10.5% SO_2 by volume and 1600° F. The gas was then assumed to be cooled in a waste heat boiler to 550° F. From the boiler the gas would pass through a cyclone and a "hot" Cottrell to a scrubber wherein the remaining dust load would be removed and gas temperature reduced to about 100° F., suitable for a metallurgical-type contact plant. This heat balance is summarized in Figure 1.

From the figures derived it was concluded that with the available concentrates, approximately 76.5% solids could be fed to the roaster to yield a gas temperature of 1600° F. Experience of the Dorr Co. indicated that in a fluid bed of this type, the rate of heat transfer was enormous, and that as a consequence temperatures would be uniform throughout the bed. Also, it was established that heat recovered would be about 2,350 lb. of steam/ton of 100% H_2SO_4. This is approximately 92% of the steam that could be theoretically obtained using moist feed as received from the mines. This heat balance was the background for the subsequent design. It may now be said that plant performance agrees well with the predicted heat balance.

With respect to sulfur dioxide strength and quality of calcine, test evidence was necessary. Some small-scale tests on 4- and 10-in. reactors had previously been run by the Dorr Co. for the American Zinc Co. Also, a 5-ft. diam. pilot FluoSolids reactor had been built by the Anaconda Copper Mining Co. and had been operated for a short period. Through subsequent discussions on experimental results and an investigation of this pilot-plant installation, it was decided that a commercial-size reactor could be built and operated successfully using a slurry of zinc concentrates as feed.

It was then decided to go ahead with a FluoSolids reactor, to be fed with a slurry of zinc concentrates; the roaster in turn to feed its gas through a conventional waste heat boiler and cleaning system into a Leonard-Monsanto metal-

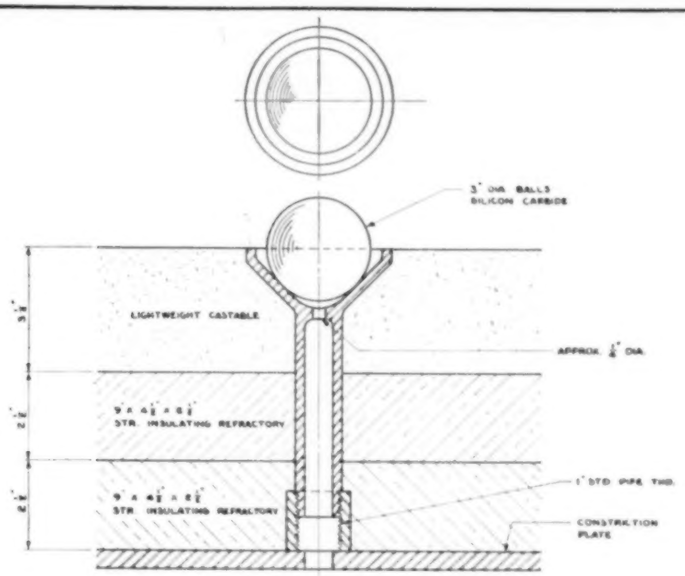


Fig. 2. Non-sifting ball check nozzles.

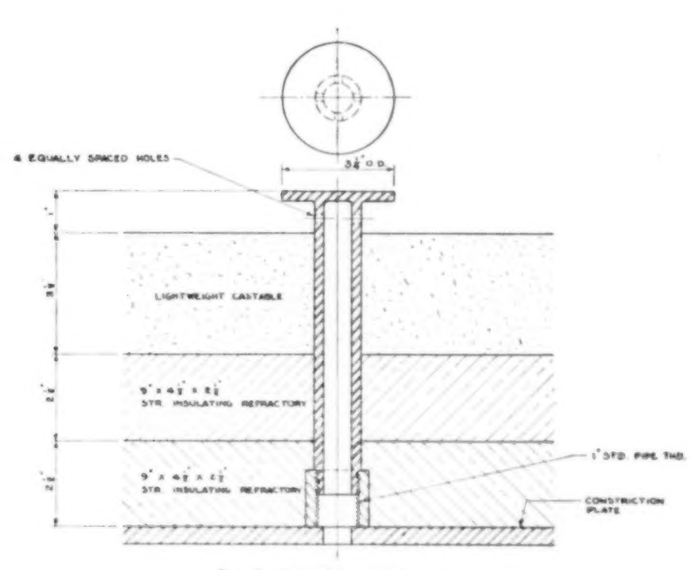


Fig. 3. Non-sifting orifice nozzle.

lurgical-type sulfuric acid plant having rated capacity of 100 tons/24 hr., 100% H_2SO_4. The product was to be in the form of 93% or 98% H_2SO_4.

Design of Plant

A. GENERAL

Many problems arose through need for speedy construction and shortage of materials at that time. However, the most interesting problems were concerned with the roasting, waste heat recovery and scrubbing operations.

B. PROBLEMS WITH ROASTER

1. Design of Roaster. The main problems were the supporting of the single hearth or bed plate and the air-inlet openings. The general construction of a FluoSolids reactor is now well known. For Alcan the design chosen was a reactor having a 22-ft. inside hearth diameter and a chamber height of 22 ft. above the bed plate. This gave a chamber floor area of about 380 sq.ft. Incidentally, 22 ft. is the largest FluoSolids reactor yet built; the largest other roaster has an I.D. of 14 ft. Small-scale test work had indicated that with flotation concentrates feed of average screen analysis 25% + 200, 45% + 325, 55% − 325, and a sulfur content of about 32%, approximately 0.39 tons concentrates/(sq. ft.)(24 hr.) could be handled. Thus the capacity of a roaster of 380 sq.ft. area would be approximately 150 tons/24 hr. zinc concentrates (dry basis). This in turn represents a figure of from 120 to 125 tons/day 100% H_2SO_4. The final figure chosen for depth of bed was 6-ft. fluidized basis. At 90 lb./cu.ft. fluidized basis this would mean 100 tons of calcine in the roaster. It was necessary to allow for these figures, as in bed plate design a 6-ft. fluidized basis is equivalent to about 4 ft. of settled calcine.

Other important points of roaster design were air-inlet openings and insulation. Original designs of small diameter FluoSolids roasters for other type ores (up to 14 ft. I.D.) had used conical openings spaced on 6-in. centers, with a silicon carbide ball check on each hole. This meant that for the Alcan roaster some 1,400 air holes, all with stainless-steel inlet nozzles, had to be used. Meanwhile a nonsifting orifice spaced on 10-in. or 1-ft. centers had been developed. This type of opening had worked well on FluoSolids reactors burning pyrite, but there was a general fear that with zinc sulfide there was danger of hole blockage due to sulfation during operation. Also, should the bed freeze, it would be extremely difficult to clean out the mess without breaking any projecting air orifice. A further advantage of the first-type openings is that they could be cleaned from below if necessary. Accordingly, Alcan installed the large number of conical openings, but left the way open for the nonsifting-type orifice as a possible future move. In the operation of roasting zinc sulfide concentrates, absolute uniformity of treatment cannot be too highly stressed. At 32% sulfur untreated material will degrade the product by 100 to 1 since preferably the calcine should not contain more than 0.30% sulfide sulfur. In practice the over-all calcine is now averaging about 0.3% sulfide sulfur. (See Figs. 2, 3.)

Mention should be made of the need for excess air. In striving to get at least 99% removal of the sulfide sulfur, 20 to 30% excess air is required. This in turn affects gas strength as shown in Figure 4. It should also be remembered that in burning ZnS or FeS_2 oxygen must be supplied to combine with both the zinc or iron and with the sulfur. The plant referred to in this paper is operating with about 20% excess air; the sulfide sulfur, as stated, is averaging about 0.3% and the gas strength 10 to 12% SO_2. From the point of view of the acid producer, lower SO_2 gas strength could be tolerated since the gas to the contact plant must be diluted to approximately 7% SO_2. A strength of 10-12% leaving the roaster gives a margin for both miscellaneous dilution and control dilution. The advantage of the FluoSolids roaster is that there is no struggle to get 7% SO_2 at the converter as is sometimes the case with more conventional roasters.

As a final point of reactor design with an assumed operating temperature of 1,600° F., the minimizing of heat loss was desired. Accordingly, a 13½-in. wall was used, consisting of 9 in. firebrick, plus 4½ in. insulating brick. The outside of the roaster shell is insulated with 2 in. of Fiberglas. It was estimated that this wall might keep heat loss down to 5% or less and that the shell would remain sufficiently warm to prevent corrosion because of sulfation.

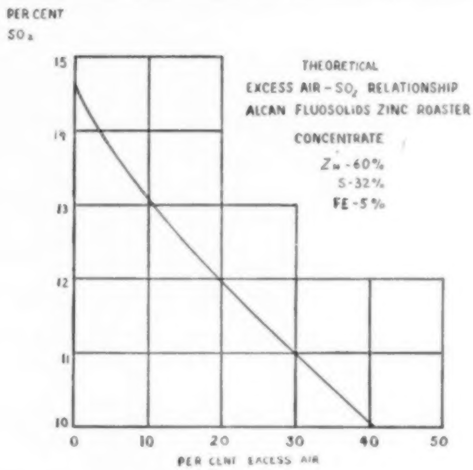
The general objective was to design a reactor which would operate smoothly and steadily, give dust-free working conditions, good heat recovery, high quality product, etc.

2. Design of Roaster Feed System. The problem of feeding the reactor was complicated inasmuch as moist (10% moisture) concentrates were to be received in a cold climate reaching 40° F. below zero as a minimum. This necessitated provision of a thawhouse, constructed largely of aluminum. Considerable debate ensued as to whether the damp concentrates as received could be fed into the roaster by means of a small screw conveyor. It was, however, believed that the screw would compress the moist cake, resulting in the formation of lumps in the roaster, which would be fatal to such a reactor. Dry feed was also considered but there was the expense of drying, and the fact that this would result in too high a temperature unless water was added in an amount equal to the amount in the slurry feed—at least according to the heat balance that was made. Alternative methods of temperature control would be recirculation of cooled gas or cooled calcine. It is reported that certain European plants are feeding pyrite dry and that they have heat exchangers in the fluid bed. However, for a project which had to "go" on time such methods of temperature control were considered too risky. It was for these reasons that so much stress had been laid on heat-balance calculations. In any case, wet feed appealed from the viewpoint of ease. Also, it was believed that a stream of particles well surrounded by water immediately would explosively disperse on entering the 1,600° F. atmosphere, thus eliminating any risk of formation of lumps. Furthermore, problems of maintaining the gas seal at the feed inlet would be minimized. The heat balance was sufficiently reassuring particularly if the sulfated dust from cyclones and Cottrell did not have to return to the circuit. It was decided to adopt wet feed.

The next problem was how best to handle the wet feed. Concentrates containing 10% moisture were coming from the mines. It was necessary to establish (a) that slurries up to 80% solids could be pumped and (b) that such slurries could be stored in agitators. Various mixtures were tested for pumpability. It was concluded that a maximum of 81.5% solids could be handled by centrifugal pumps. At first it was thought that high speed and consequently high horsepower agitation would be necessary. However, test work established that these concentrates could be successfully handled by Dorr agitators rotating at about 6 rev./min. This whole question was important in view of the desire to have several hundred tons of concentrates in suspension to eliminate shift and week-end work in slurry preparation.

Moyno screw-type pumps seemed to be a good choice for feeding the roaster but as an additional precaution oversize pumps were specified. A decision was also made to feed the roaster at two points in the belief that this would give good feed distribution in the large reactor which had been selected. For transferring slurry from storage agitators to feed agitators, centrifugal pumps were adopted—rubber-lined VacSeal pumps.

Fig. 4.



The feed system may be described briefly as wet concentrates into a pug mixer, into storage tanks by gravity, into feed agitators by a VacSeal pump, and finally by Moyno pumps into the roaster. The feed is introduced onto the top of the bed. The "freeboard" temperature is only 25° F. to 50° F. below the bed temperature.

The feed system appears to be generally sound. Smooth and uniform roaster operation is being obtained.

3. Reactor Discharge. The reactor discharge takes place in two principal ways. Part of the calcine overflows at the discharge outlet, the rest passes out with the gas where it is eventually deposited in the waste heat boiler, cyclone or hot Cottrell. An important question in designing the plant was whether or not to return boiler, cyclone and Cottrell dust to the reactor. These various dusts were expected to be progressively higher in sulfate. However, it was expected that the dust collected in the boiler would not be too heavily sulfated and that perhaps the fraction passing on to cyclones and hot Cottrell would not be so heavily sulfated as to put the average content of $ZnSO_4$ in the product over acceptable limits. Furthermore, the close heat balance of the wet feed Fluosolids roaster would be adversely affected by the return of $ZnSO_4$ since the reaction of $2\ ZnSO_4 \rightarrow 2\ ZnO + O_2 + 2\ SO_2$ is endothermic. Also opposing dust return was the possibility of building up a circulating load of dust. Following this reasoning it was decided not to return the various dusts to the reactor. However, the possibility that such dusts might have to be returned to the reactor or otherwise treated at some future date was not discounted.

In practice, using a flotation concentrate averaging about 25% + 200 mesh and a total of 45% + 325 mesh, and when operating at a rate of about 140 dry tons concentrates/day, it was found that about 30% overflows the roaster. The other 70% is divided approximately as follows: boiler 23%, cyclone 44%, hot Cottrell 3%.

Handling of such dusts is conventionally done by screw conveyor. However, in this installation extensive use was made of Fuller-Huron airslides with excellent success. Screw conveyors are still used directly under the boiler, cyclone, and hot Cottrell, but thereafter airslides effect transfer to and from the cooler and to the Fuller-Kinyon pumps which transfer the calcine to storage bins.

C. INSTRUMENTATION

Considerable emphasis was placed on instrumentation. The general desire was to have adequate, but not excessive instrumentation, centralization of the instruments and controls, and good protection for instruments.

Remote control of certain operations was desirable. It is also particularly im-

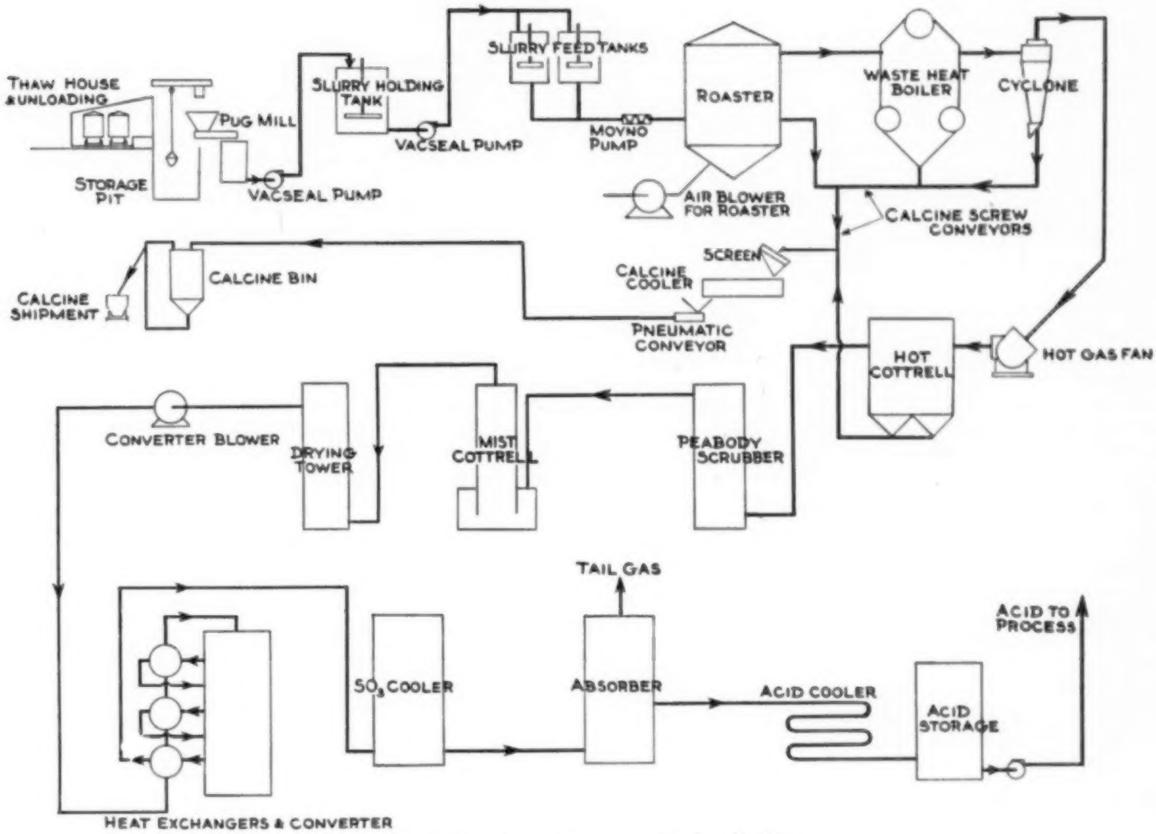


Fig. 5. Flow sheet—zinc roasting sulfuric acid plant.

portant that close control of pressures be maintained in a gas flow system containing much fine dust in suspension and strong sulfur dioxide.

Air enters the reactor windbox at from 4 to 6 lb./sq.in. Unlike other types of roasters there is no necessity to open doors. Except for the danger of sulfating the steel shell there is no need to worry about roaster pressure. FluoSolids reactors operating on pyrite often operate under pressure as usually they are directly followed by a cyclone, and do not have any waste heat boiler. However, as a waste heat boiler and cleaning system is used in this case, pressures must be maintained slightly negative. To meet this situation remote control was employed at two key points in the system. In Figure 5, it will be noted, that these key points are the hydraulic coupling controlling speed of the hot-gas fan following the waste heat boiler and cyclone, and the butterfly damper ahead of the main blower in the contact section of the plant. By either manual or automatic control, the operator in the roaster control room is able to keep the entire roasting and cleaning system under slight negative pressure at all times. This minimizes air inleakage to the system. If desired the entire system may be put under stronger suction. The speed of the Moyno pumps may be regulated from the control room.

Levels in acid storage tanks several hundred feet away may be read in the contact control room by means of remote pressure indicators operated from air bubblers in the tanks. This system operates well.

In general, up-to-date electronic-type instruments have been used. There are two control rooms, one for the roasting and cleaning operation, the other for the contact plant. Both are strongly lighted with modern fluorescent lighting and separate outside air ventilation provided. All instrument panels are set well away from walls for ease of maintenance. A pleasant color scheme makes the two control rooms attractive centers. As in the thawhouse extensive use has been made of aluminum in control-room construction. Kingstron stucco embossed-aluminum sheet makes an attractive nonglaring surface which requires no maintenance. The control provided by the above instrumentation has been found particularly useful in starting the plant after planned or unexpected shutdowns.

General Comment—Operating Troubles and Results

The plant first started operations on June 10, 1952. By the end of 1952 some 17,000 tons of concentrates dry basis had been processed for an acid production of about 14,000 tons 100% basis.

Apparently as must be expected there were a few start-up troubles. It must be emphasized that in the construction of such a reactor the windbox must be completely airtight. In this particular case, certain leaks around the periphery of the shell permitted the air blast to erode the insulating brick next to the shell and serious air by-passing resulted.

Alcan developed a fluidized water-cooled calcine cooler of its own design and considerable effort was necessary to achieve good operation. The trouble experienced in getting this external cooler to function properly does not encourage one to install pipe coolers or heat exchangers in the bed of the roaster.

In the feed system little trouble was encountered after protective screens were installed before the VacSeal pumps.

The boiler lancing has turned out to be a fair amount of work and there is an incentive to develop a practical cyclone which would remove the dust load ahead of the boiler and yet not produce too many other troubles. Such a development would be a prime factor in producing a calcine with lower sulfate sulfur content.

The horizontal flow hot Cottrell appears to be performing with high efficiency and the Peabody-type scrubber is satisfactory.

Except for minor mechanical equipment difficulties in start-up, the Leonard-Monsanto contact acid plant is performing well.

Perhaps the major fault in design came about as the result of fitting the plant into an existing building. Because of column loadings it was not possible to place the boiler closer than 10 ft. from the roaster. As a consequence there has been considerable build-up of sulfate scale in the 10-ft. breeching between the roaster and the boiler. Presumably there is a radiation cooling effect when the 1,600° F. gas in the breeching and the walls of the breaching "see" the cold black boiler tubes. So far this scaling is causing a two-day shutdown each month for cleanout purposes. Provision is being made for cleaning out this scale on the run. Scale so formed along with scale which forms on the first rows of boiler tubes will be crushed and screened in close circuit during operations and passed out with the calcine product. Table 1 (below) indicates typical operating figures.

Acknowledgments

The authors acknowledge the advice and co-operation of Alcan executives A. W. Whitaker, Jr., and M. P. Weigel. Much credit is also due K. A. Phillips, American Zinc, Lead & Smelting Co. and others of that organization. The work of the Dorr Co. was very helpful, particularly that done by C. H. Knight, T. B. Counselman and H. McAskill. The pioneering pilot plant contribution of Anaconda Copper Mining Co. is recognized with appreciation, especially the co-operation of F. F. Frick and F. L. Holderreed. Credit is also due H. G. Burbidge, who did the major part of the work on the heat and material balance.

TABLE 1.

NOVEMBER, 1952

Total concentrates consumed		3,190 dry short tons
Analysis concentrates consumed	Zn	58%
	S	31%
	Iron	3-5%
	Lead	0-1%
	Other	8-5%
Screen analysis		25% + 200 45% + 325
Sulfur in concentrates		994 short tons
100% acid produced		2,570 short tons
Zinc calcine produced		2,884 short tons
Sulfur efficiency		86%
Analysis of calcines produced		
Total zinc		64.30
% sulfide sulfur		0.34
% sulfate sulfur		2.11
Tons concentrates/ton 100% acid		1.26
Tons calcine/ton concentrates		0.90
Pounds net steam/ton 100% acid		2,350
Slurry density avg. % Sol.		77.4
Roaster temp. avg. ° F.		1,607
Freeboard		1,511*
Waste heat boiler outlet		464° F.
Hot Cottrell Outlet		445° F.
% Lost time		8.9

* There was some air by-passing at the time.

Discussion

Herbert Kay (Pittsburgh Consolidation Coal Co., Library, Pa.): What about the interrelationships between size of the material being fed to the FluoSolids roaster, velocity in the roaster, carry-over of solids resulting from this velocity, and temperature gradients experienced?

T. T. Anderson We have a space rate of about 1 ft./sec. in that bed and in the range in which we have operated I don't think we have noticed anything. There is no temperature gradient in the bed which we can measure.

Herbert Kay: Referring to 1 ft./sec., you mentioned zinc concentrates of the order of 55%-325 mesh. Is that prior to feeding to the pumps or after discharge of the pumps?

T. T. Anderson: I've been trying to get a little information on that same thing myself. The information we have to date indicates that the mixed material, that is, the total calcine from all sources, whether it be roaster, boiler, etc., is no smaller than the feed. In fact, there is some indication that it wasn't as small, which might be explained by the sulfation in the hot Cottrell and elsewhere but I wouldn't want to give a definite answer to that. We might be able to answer a little more accurately a year from now.

Herbert Kay: Do you have some quantitative figures on carry-over of solids from the FluoSolids bed? What per cent do you get out of the bottom?

R. Bolduc: For the carry-over we have 25% deposited in the boiler, 50% in the cyclone, 2% in the hot Cottrell, and about 23% overflowing the roaster.

T. T. Anderson: In respect to this carry-over we are handling a finer concentrate now than we had contemplated, and finer than I have indicated in my figures.

V. W. Uhl (Bethlehem Foundry & Machine Co., Bethlehem, Pa.): Concerning the fusion of the material in the reaction bed, how close a temperature control is it necessary to hold?

R. Bolduc: So far we have not had any trouble with fusion and the control probably can maintain bed temperature within 5° F. We operate at the present time at 1,600° F. The temperature control is automatic.

V. W. Uhl: What is the percentage of lead in the zinc flotation concentrate that was treated in the roaster?

R. Bolduc: Per cent of lead so far was not more than 1%.

Presented at A.I.Ch.E. Toronto Meeting.

Transition Flow of Fluids in Smooth Tubes

V. E. Senecal and R. R. Rothfus   Carnegie Institute of Technology, Pittsburgh, Pennsylvania

Characteristics of laminar-turbulent transition have been studied by measurement of point velocities and static pressure differentials in air flowing isothermally through two smooth tubes. Data have also been obtained in the viscous and lower turbulent flow ranges. The presence of turbulence was observable at bulk Reynolds numbers greater than about 1,000. The major transition, which occurred in the narrow Reynolds number range between 2,100 and 2,800, was marked by extreme changes in the velocity profile. Data obtained in the lower turbulent zone were in agreement with those of previous investigators.

Laminar-turbulent transition in fluids flowing through conduits is of considerable practical and theoretical importance. The literature, however, contains few reliable data in this range of flow. The present investigation was undertaken to supply much-needed experimental information on isothermal velocity distribution and fluid friction in smooth tubes throughout the zone between purely viscous and fully turbulent motion.

Flow characteristics at both ends of the transition range have been fairly well established by previous investigators. There appears to be ample experimental evidence that in truly laminar, steady, isothermal flow through tubes there is no appreciable slip at the walls, the Fanning friction factor is inversely proportional to the bulk Reynolds number, and the velocity distribution is parabolic as predicted by elementary theory. In fully developed turbulence at Reynolds numbers below 100,000, the empirical friction factor correlation of Blasius (1), viz.,

$$f = 0.079\ N_{Re}^{-0.25} \qquad (1)$$

appears to fit published data with sufficient accuracy.

The velocity distribution at low turbulent Reynolds numbers is only approximately known. Data of several investigators (*2, 5, 8*) indicate that even though the main-stream velocity profile at a particular value of the Reynolds number is represented satisfactorily by the equation

$$\frac{\mu}{\sqrt{\tau_o/\rho}} = A + B \ln\left[\frac{y\rho\sqrt{\tau_o/\rho}}{\mu}\right] \qquad (2)$$

the effect of Reynolds number on the values of A and B is appreciable in the lower turbulent range. Equation (2) with A = 5.5 and B = 2.5 can, however, be viewed as a rough approximation to the main-stream velocity distribution over the entire range of full turbulence.

Although the transition zone has thus been more or less successfully bracketed, little has been done to trace out the alterations in flow characteristics which accompany the onset of stable turbulence. Numerous publications have shown Fanning friction factors to increase sharply over those predicted by viscous flow theory in the Reynolds number range from 2,000 to 3,500. Lack of precision and variations in experimental technique have made it extremely difficult, however, to predict either the friction factor or the true extent of the transition zone from these data. A few measurements of local velocities in transition have been made by Morrow (*4*), but his data fail to meet the requirements of theory in laminar motion and, therefore, appear to be unreliable. Stanton and Pannell (*10*) have experimentally determined the ratio of average to maximum velocity at three transition Reynolds numbers. Their data appear to be reliable but too limited to be conclusive.

Scope of the Investigation

The principal objectives of the present experiments were the following:

1. To obtain additional information on fluid friction in transition zone from precise measurements of static pressure differentials.
2. To measure distribution of main-stream local velocities by means of minute impact tubes.
3. To supplement previous data on ratio of average to maximum velocity in transition range.
4. To establish, for one type of entrance, the true extent of transition zone and the reproducibility of data within this zone.
5. To supplement data of previous investigators in lower turbulent range and check present data with theoretical predictions in truly laminar flow.

No attempt was made to obtain local velocities near the pipe wall because impact tubes do not appear to be reliable in this region (*5, 7, 9*). Furthermore,

---

V. E. Senecal is associated with the E. I. Du Pont de Nemours & Co., Inc., Wilmington, Del.

Original data and calibrations are available on interlibrary loan from Carnegie Institute of Technology, Pittsburgh 13, Pa.

only a square-edged entrance with an ordinary magnitude of disturbance was used in order to maintain the effect of entrance conditions at a practical level. The experiments were performed on air at room temperature flowing steadily and isothermally through smooth brass tubes of ½-in. and ¾-in. I.D. Data were obtained at Reynolds numbers between 600 and 10,000.

Experimental Apparatus

Although the present investigation was confined to the flow of air, the apparatus was capable of handling both gases and liquids. Figure 1 shows the combined system, but further description will be limited to the gas flow unit.

Room air was moved by a blower into the all-brass piping system. The flow rate to the system was controlled by a by-pass regulator and two V-port valves. A cooling unit was provided to insure isothermal flow. The air leaving the cooler passed through a section of flexible tubing, inserted in the line to minimize vibration, and then to a small cylindrical surge tank which contained a glass wool filter. The main surge tank was a 2-ft. cube fitted with an adjustable packing gland through which the test pipes were inserted.

The test sections were lengths of smooth yellow brass tubing having inside diameters of 0.500 in. ± 0.002 in. and 0.750 in. ± 0.002 in. The ½-in. tube was assembled in three sections 12, 4, and 8 ft. long respectively in the direction of flow. The corresponding lengths of the ¾-in. tube were 12, 4, and 10 ft. To preserve internal alignment, the ends of the sections were alternately shouldered and recessed. The angle iron framework on which the tubes rested was fitted with adjustable supports, which allowed the tubes to be locked into the axial position determined by use of a transit theodolite. The upstream test section extended into the surge tank and formed a sharp-edged entrance. Air, leaving the downstream test length was led to either of two individually calibrated rotameters and subsequently discharged to the atmosphere.

Five static pressure taps were installed in the positions shown in Figure 1. The taps were formed from flared tubing fittings ground concave and soldered over precision-drilled holes in the test sections. All static pressure leads were formed from fully annealed copper tubing. Pressure differentials were measured by either of two manometers. One of these was an ordinary vertical U-tube manometer filled with a red oil (manometer 2 in Fig. 1). The other (micromanometer 3) was a tilting-type instrument such as used by Rothfus, Monrad, and Senecal (7). Both pressure leads to this unit were fitted with short lengths of hypodermic tubing to dampen pulsations.

Velocity profiles were obtained in the 4-ft. test section at a point 3 ft. from the upstream end. A precisely machined traversing mechanism held the impact tube and allowed its opening to be located in the fluid section with an accuracy of ±0.001 in. Impact tubes were formed from stainless steel hypodermic tubing and had internal diameters of 0.013, 0.020, and 0.028 in. They were of bent design in each case and were ½ in. long in the direction of flow. The reference position of the impact tubes was established by electric contact with the pipe wall. Total and static pressures for the velocity measurements were obtained at the same plane normal to the mean flow of air. The impact pressure was measured by either of two micromanometers. At low flow rates, a bubble-type instrument similar to that described by Falkner (3) was used (micromanometer 1). At higher flow rates, a micromanometer such as that used for static pressure measurements proved satisfactory (micromanometer 2). The pressure leads were similar to those of the static pressure sys-

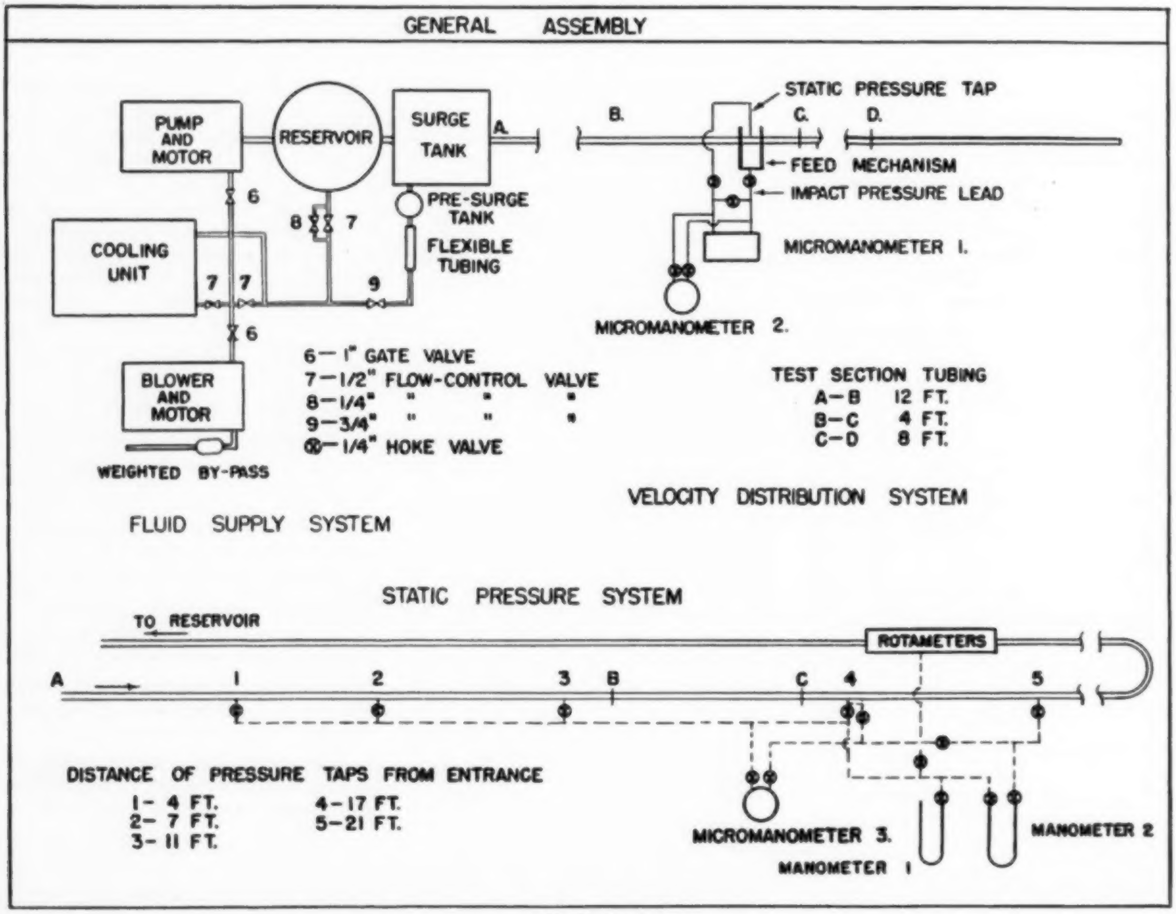


Fig. 1. Apparatus.

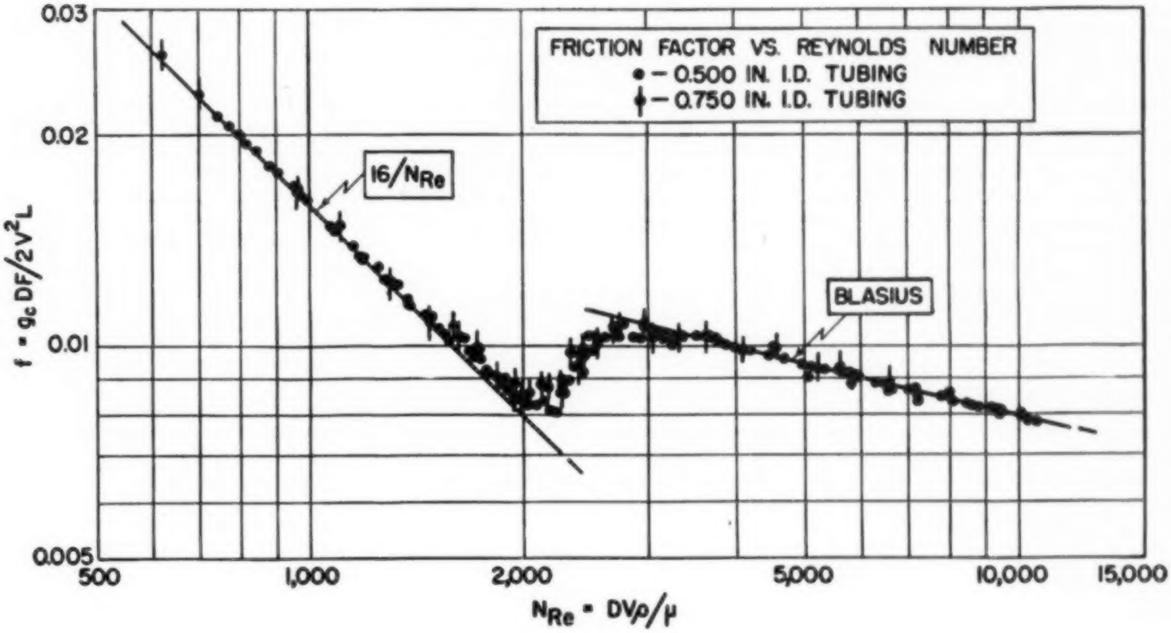


Fig. 2. Friction factor vs. Reynolds number.

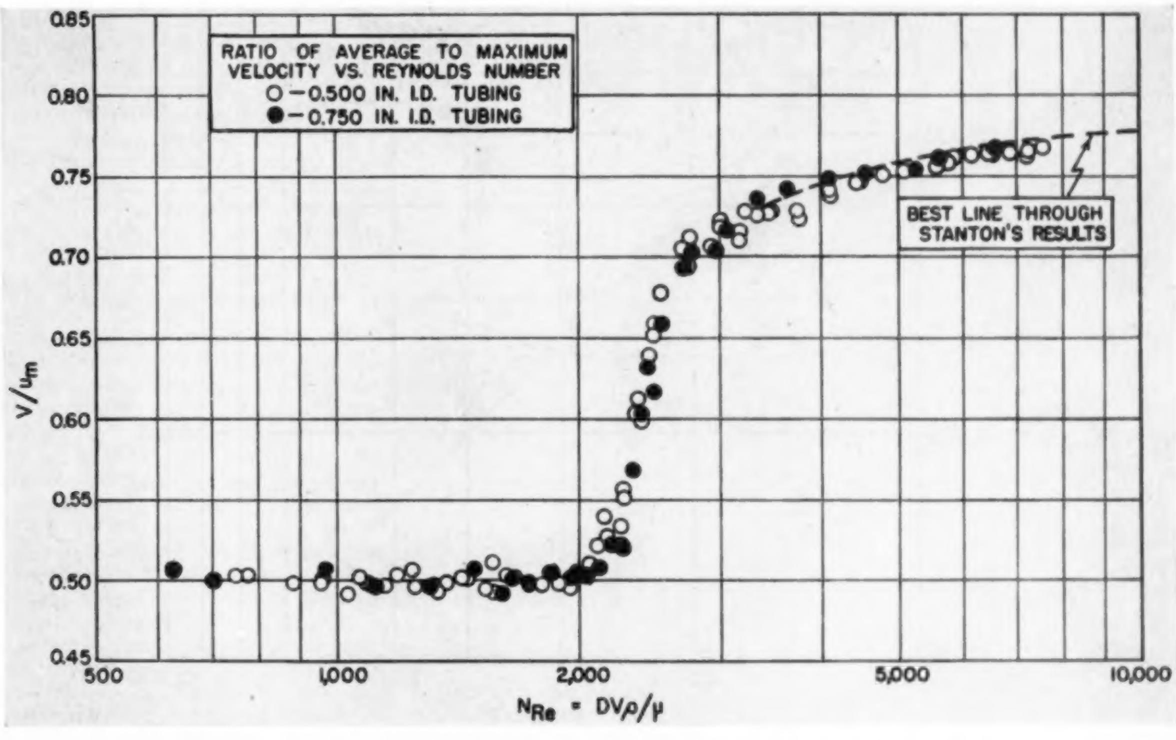


Fig. 3. Ratio of average to maximum velocity as a function of the Reynolds number.

tem and the micromanometers were again buffered by hypodermic tube resistances.

The temperature of the flowing air was determined from the action of a thermocouple situated in the test section a short distance from the entrance. The room temperature was measured by a precision thermometer with scale intervals of 0.1° C. Barometric readings were obtained with a vertical mercury barometer having the precision of 0.1 mm. Hg. The static pressure in the system at the rotameter position was measured on an open-end U-tube (manometer 1). The entire apparatus was protected from building vibrations by rubber pads installed under the supporting framework. It was sought to attain a practical vibrational level in the equipment rather than one which could be reproduced only by extraordinary measures.

Experimental Procedure

The reproducibility of pressure-drop data was tested by varying (1) the direction of approach to a prescribed flow rate (2) the Reynolds number interval between successive test conditions, and (3) the time which was allowed to elapse between the attainment of steady flow and the actual taking of data. In each case, the pressure drop was measured over the maximum tube length permitted by the operating range of the micromanometer being used. Fluid properties were taken to be those at the temperature and length-average static pressure in the test section.

The majority of velocity distribution and pressure-drop data were obtained in separate runs, but some were taken simultaneously to permit direct comparison. It was thus possible to determine the relationship among friction factors and Reynolds numbers based on maximum rather than average fluid velocities. Each velocity distribution run provided a value of the ratio of average to maximum fluid velocity, but these data were supplemented by a number of runs in which only the axial and average velocities were measured.

The value of the impact tube coefficient was checked in streamline motion by comparing theoretical point velocities with those calculated from experimental impact pressures on the assumption of unit coefficient. At Reynolds numbers above the fully viscous range, profiles were obtained with all three sizes of impact tubes, and velocities at corresponding points were corrected by extrapolating to the conditions of zero impact tube diameter. Symmetry of the velocity distributions was checked by obtaining data at points on both sides of the pipe axis.

After installation of the test section, the impact tube to be first used was positioned by electric contact with the pipe walls and all static pressure taps were tested for uniformity of pressure gradient between successive stations. Experimental runs were begun by adjusting the air flow rate to a rough value based on the desired Reynolds number. It was found that isothermal flow through the test section could be closely approached by passing the whole quantity of air through the cooler without introducing coolant other than the room air itself. After conditions in the test section were calculated from the inlet temperature and the absolute pressure at the rotameters, fluid properties were determined and the final adjustment of the flow rate was made. Necessary impact- and static-pressure data were then obtained from the appropriate micromanometers. In each case, pressure fluctuations were averaged visually when the instruments were read.

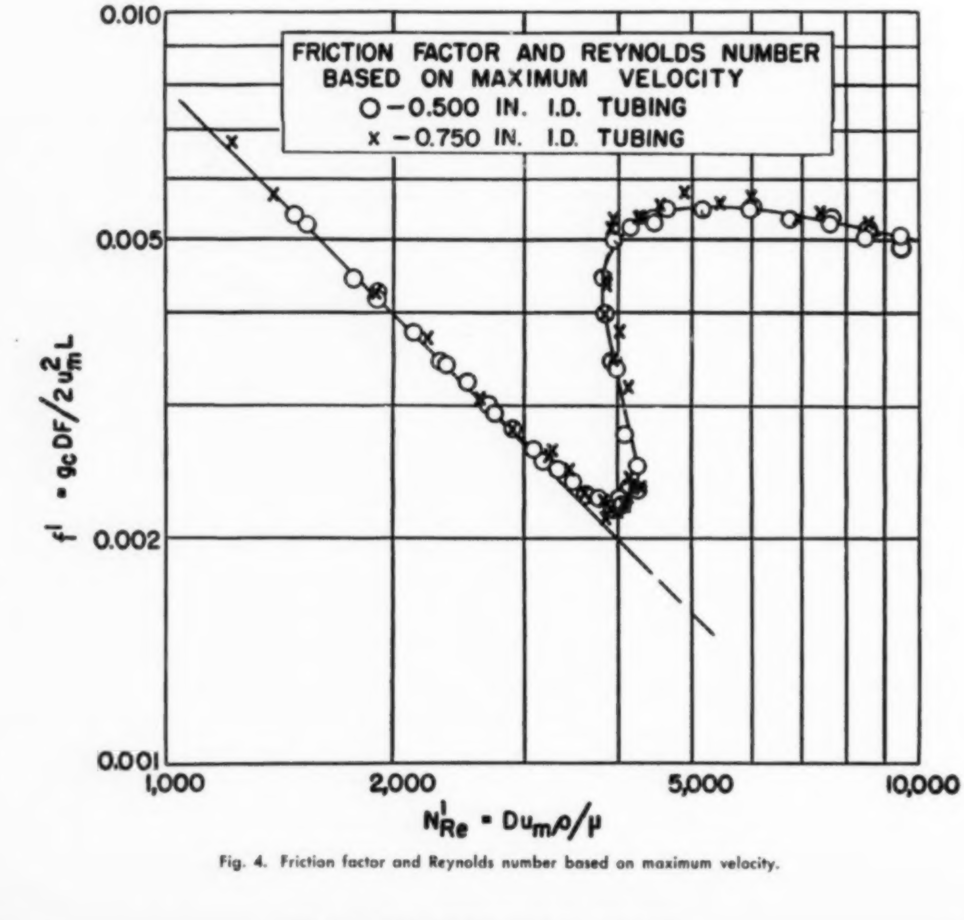


Fig. 4. Friction factor and Reynolds number based on maximum velocity.

Results

Experimental results are presented in Figures 2 to 6. Figure 2 indicates that the friction data were reproducible and independent of time and direction of approach to the desired Reynolds number. The region of rapid change in the friction factor is seen to be limited to Reynolds numbers between 2,100 and 2,800. The Blasius correlation is met, however, only at Reynolds numbers above 3,500, and some deviation from the laminar relationship is observable at Reynolds numbers between 1,000 and 2,100. The friction factor in the transition zone appears to be a single valued function of the Reynolds number.

Figure 3 shows the ratio of average to maximum fluid velocities to be in close agreement with those of Stanton in the lower turbulent range. Again, the greatest change in the ratio occurs at Reynolds numbers between 2,100 and 2,800. Below 2,100 Reynolds number, the value of the ratio appears to be constant within the limit of experimental accuracy.

When friction factors and Reynolds numbers are based on maximum rather than average fluid velocities, a reverse curve becomes evident in the transition zone as shown by Figure 4. This can mean only that the maximum velocity decreases with increased Reynolds number in the region of rapid transition. The velocity profiles shown in Figures 5 and 6 indicate that the decrease in maximum velocity is accompanied by a sudden flattening of the main stream distribution. The lowest profile in each pipe is in close agreement with the parabolic distribution based on the same bulk average velocity. Deviation from parabolic flow increases steadily up to 2,100 Reynolds number where the rapid alteration in the profile takes place. Full turbulence appears to be established at a Reynolds number somewhat below 4,000.

Discussion of Results

It is believed that significant experimental errors were confined to the rotameter and micromanometer readings. Both flowrators were individually calibrated by the manufacturer with a stated precision of $\pm 0.5\%$. In the lower flow range of each meter, the maximum error appeared to be about 1.5% of the measured rate. Micromanometers 2 and 3 could be read with a precision of 0.0001 in. of water. The action (micromanometer 1) involved the growth of a paraxylene bubble in water and yielded readings which could be reproduced with a precision of 0.00002 in. of water. The maximum error in the friction measurements caused by the micromanometer was estimated to be 1.2% of the pressure drop in the worst case and much less than this over most of the Reynolds number range investigated. The percentage error in the point velocity measurements caused by the micromanometers was dependent on Reynolds number, tube diameter, and distance from the tube wall. In the worst case, the maximum error was estimated to be 6% of the velocity. The necessity of visually averaging the effect of pressure fluctuations in the micromanometers produced an indeterminate error.

At the lowest Reynolds number in each tube, comparison of measured velocities with the parabolic profile drawn to the observed average velocity indicated that all three impact tubes operated with coefficients of unity. At Reynolds numbers above the laminar range, comparison of integrated and observed average velocities showed further calibration of the impact tubes to be necessary. Accordingly, corrected point velocities were obtained by extrapolating corresponding data obtained with the three sizes of impact tubes to zero tube diameter. In this manner measured velocities near the wall were found to decrease slightly with decreasing impact tube diameter. Comparison of observed average velocities with those obtained by integrating the corrected velocity profiles indicated that the mean value of the integrated velocity was 1.40% high in the ½-in. tube and 0.92% high in the ¾-in. tube. The corrected profiles were compared with parabolic distributions drawn to the same value of the skin friction. By this means, the two point velocities closest to the wall of the tube were found to be too high in each case where appreciable turbulence was present at the points in question. The error in these velocities was sufficient to account for most of the difference between the integrated and observed average velocities. The action of the impact tubes was further evidence that such tubes are not reliable in the vicinity of a solid boundary even

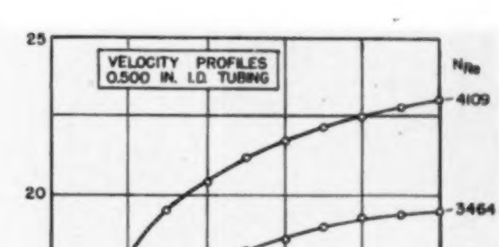


Fig. 5. Velocity profiles in ½-in. diameter tubing.

though they are reasonably satisfactory in the main fluid stream.

Data of Figure 4 appear to scatter even less than those of Figure 2. This indicates that maximum velocities were obtainable with greater precision than bulk average velocities. It does not mean, however, that the accuracy of the maximum velocities was necessarily greater.

Both the velocity-distribution and pressure-drop data indicated the presence of turbulence in the fluid at Reynolds numbers greater than about 1,000. At the lowest Reynolds number investigated in each pipe, the deviation from the parabolic profile was so slight that it was necessary to compute the velocity gradient in order to detect turbulence near the center of the stream. The departure from parabolic flow was progressive with increased Reynolds number and was shown by both the velocity profiles and friction factors. This was in agreement with the dye traverses of Prengle (*6*) who reported that stable turbulence in tubes was first observable in the center of the fluid stream at a Reynolds number of 930 and spread outward at a predictable rate as the Reynolds number was further increased.

The effect of main-stream turbulence on the skin friction was not great at Reynolds number less than 2,150. Furthermore, even though the departure from the parabolic velocity distribution was appreciable at Reynolds numbers immediately below 2,150, the ratio of average to maximum velocity remained close to 0.50, its value in fully laminar motion. Only above 2,150 Reynolds number, the value at which Prengle found that cross-currents first penetrated almost to the wall, was the skin friction appreciably increased and the velocity profile greatly altered.

The Fanning friction factors obtained at Reynolds number greater than 3,300 were represented closely by the correlation of Blasius. Velocity profiles in the neighborhood of 4,000 Reynolds number were in essential agreement with those of previous investigators. It is notable that the turbulent profiles obtained in the present experiments were in better agreement with the data of Stanton and Fage than with those of Nikuradse. The same was true of the ratio of average to maximum velocity in the lower turbulent region.

The upstream calming length was sufficient to insure a fully developed velocity distribution at the point of measurement. It should be remembered, however, that the present experiments were limited to tubes with square-edged entrances. Data should be used with caution when other entrance shapes are involved until more extensive information on their effect is available.

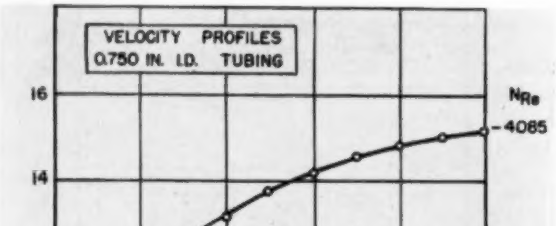


Fig. 6. Velocity profiles in ¾-in. diameter tubing.

Acknowledgment

The authors wish to thank Carl C. Monrad for numerous valuable suggestions and the E. I. du Pont de Nemours & Co., Inc., for fellowship assistance.

Notation

A, B = numerical constants, dimensionless
D = inside diameter of tube, ft.
f = Fanning friction factor = $g_c DF/2V^2L$
f^1 = friction factor based on maximum velocity = $g_c DF/2u_m^2L$, dimensionless
F = friction in energy balance = $\Delta p/\rho$ (ft.)(lb. force)/(lb.)
g_c = conversion factor = 32.2 (lb. mass) (ft.)/(lb. force)(sec.)^2
L = axial length of tube over which Δp is measured, ft.
N_{Re} = bulk Reynolds number = $DV\rho/\mu$, dimensionless
N_{Re}^1 = Reynolds number based on maximum velocity = $Du_m\rho/\mu$
Δp = static pressure drop caused by fluid friction, lb. force/sq.ft.
u = local fluid velocity, ft./sec.
u_m = maximum local fluid velocity, ft./sec.
V = average fluid velocity, ft./sec.
y = distance from tube wall, ft.
μ = absolute fluid viscosity, lb. mass/(sec.)(ft.)
ρ = fluid density, lb. mass/cu.ft.
τ_o = shearing stress at tube wall, poundals/sq.ft.

Literature Cited

1. Blasius, H., *Mitt. Forschungsarb.*, **131**, 1 (1913).
2. Fage, A., *Phil. Mag.*, **21**, 80 (1936).
3. Falkner, V. M., *Aero. Res. Com. Rep. & Mem.* No. 1589 (1934).
4. Morrow, J., *Proc. Roy. Soc.*, **A76**, 205 (1905).
5. Nikuradse, J., *V.D.I. Forschungsheft*, **356** (1932).
6. Rothfus, R. R., and R. S. Prengle, *Ind. Eng. Chem.*, **44**, 1683 (1952).
7. Rothfus, R. R., C. C. Monrad, and V. E. Senecal, *Ind. Eng. Chem.*, **42**, 2411 (1950).
8. Stanton, T. E., *Proc. Roy. Soc.*, **A85**, 366 (1911).
9. Stanton, T. E., D. Marshall, and C. N. Bryane, *Proc. Roy. Soc.*, **A97**, 413 (1920).
10. Stanton, T. E., and J. R. Pannell, *Phil. Trans. Roy. Soc.* (London), **A214**, 199 (1914).

Measurement and Correlation of Thermal Conductivities of Gases at High Pressure

J. M. Lenoir, W. A. Junk, and E. W. Comings

Purdue University, Lafayette, Ind.

The thermal conductivity of gases at high pressure have been measured previously by Sellschopp (*7*), Vargaftik (*9*), Keyes and Sandell (*4*), and Lenoir and Comings (*5*). The apparatus used in this investigation has been described by Lenoir and Comings. The thermal conductivity of nitrogen, methane and argon was measured at 127° F. and that of ethane at 107° F., 134° F., and 153° F. over a pressure range from 1 to 200 atm. The ethane exhibited an anomalous variation of thermal conductivity compared with other gases.

Briefly, the measurements were made by passing heat radially through an annular layer of gas 0.008 in. thick. This layer was in series with a similar layer of a standard gas. The apparatus was calibrated with gases of known thermal conductivity in the test gas annular space at one atmosphere and was then used to determine the unknown value of the thermal conductivity at elevated pressures. Errors caused by radiation across the annular spaces have been shown to be negligible. Small corrections were applied for apparatus end effects and for the increase in gas layer thickness caused by the increase in pressure. A detailed discussion of the method is to be found in the previous article (*5*). Results are listed in Tables 1-4, inclusive.

The thermal conductivity ratio is defined as the thermal conductivity k at any pressure P divided by the thermal conductivity at atmospheric pressure k_1, where both conductivities are at the same temperature. The results for methane, nitrogen and argon, listed in Tables 1-3 are plotted on Figure 1 as the thermal conductivity ratio as a function of reduced pressure. They are compared in this figure with the correlation developed by Comings and Nathan (*1*). The correlation is denoted by the solid lines at constant reduced temperatures. The arrow denotes the line with which the measured values are to be compared. The agreement of the correlation with the nitrogen data is excellent. The correlation predicts somewhat low values for argon, and high values for methane.

Gamson (*3*) presented a general correlation for thermal conductivity at high pressure at a time when few experimental measurements had been made. The thermal conductivity of argon and methane predicted by this correlation differ from the measured values by less than 15%. The values predicted for nitrogen are from 19 to 25% too high and those for ethane are as much as 47 to 70% too high.

On Figure 1 the results previously obtained on ethylene and carbon dioxide (*5*) are also plotted. The dotted lines represent the experimentally determined values; the solid lines, the Comings and Nathan correlation. The correlation does not fit the measured values well when the gas is close to the critical state, but predicts a good average value for gases relatively far from the critical state. In general it appears that a correlation could be developed based on measurements now available which would be an improvement on the earlier one based on predicted values.

So new a correlation has been developed which will avoid the large discrepancies in the region close to the critical state. Smoothed curves representing the experimental thermal conductivity ratios of the various gases were prepared. Values of k/k_1 were read from these curves at convenient intervals of reduced pressure. These values were plotted vs. reduced temperature at constant reduced pressure in Figure 2. Values of thermal conductivity ratio read from this figure were then plotted against reduced pressure on curves at constant reduced temperature as shown by Figure 3. This figure is the new and improved general correlation for predicting the thermal conductivity ratio of any gas when its critical temperature and critical pressure are known. This graphical procedure was also employed in obtaining the curves for pressures below the critical pressure. Data in this range on nitrogen and methane and also the earlier data of Lenoir and Comings on ethylene and carbon dioxide are plotted on Figure 4. Certain values determined by Sellschopp (*7*) at temperatures below the critical temperature are also included in Figure 4. Although convection was suspected of being present in some of Sellschopp's measurements these values were not made under conditions which would lead to convection. The low pressure portion of Figure 3 was obtained from Figure 4.

Table 4 shows the measured values obtained with ethane at three temperatures. This gas, which had a stated purity of 99.0%, was supplied by the Phillips Petroleum Co. The gas was used as received without further purification. Although the behavior of the ethane is somewhat similar to that of carbon dioxide, its thermal conductivity varies in an anomalous manner in the high pressure region. An irregularity exists in the 107.5° F. isotherm between a reduced pressure of 1.19 and 1.39 (58 and 68 atm.) as shown by Figure 5. Since this is the region in which the temperature coefficient of expansion is greatest, it is the region in which con-

---

J. M. Lenoir is now associated with University of Denver, Denver, Colo.

W. A. Junk, Standard Oil Company (Indiana), Whiting.

TABLE 1

Thermal Conductivity of Nitrogen at 127° F.

PRESSURE ATM.	THERMAL CONDUCTIVITY B.t.u./(hr.)(sq.ft.)(° F./ft.)
1.0	0.0162
16.7	0.0167
30.9	0.0170
49.3	0.0175
68.6	0.0179
89.3	0.0185
109.1	0.0191
129.6	0.0200
148.8	0.0204
169.8	0.0213
187.3	0.0218
203.7	0.0225
216.7	0.0226

TABLE 2

Thermal Conductivity of Methane at 127° F.

PRESSURE ATM.	THERMAL CONDUCTIVITY B.t.u./(hr.)(sq.ft.)(° F./ft.)
1.0	0.0220
9.4	0.0223
15.2	0.0223
29.5	0.0228
42.6	0.0238
55.3	0.0243
66.8	0.0250
96.1	0.0272
110.4	0.0282
136.6	0.0304
150.7	0.0312
164.1	0.0321
174.9	0.0333
190.4	0.0343
203.0	0.0361

TABLE 3

Thermal Conductivity of Argon at 127° F.

PRESSURE ATM.	THERMAL CONDUCTIVITY B.t.u./(hr.)(sq.ft.)(° F./ft.)
1.0	0.0114
14.4	0.0115
29.8	0.0119
42.9	0.0122
55.8	0.0124
67.9	0.0127
77.2	0.0132
95.6	0.0133
109.6	0.0136
122.2	0.0143
137.8	0.0146
163.0	0.0156
176.6	0.0159
189.8	0.0163
202.9	0.0164
217.4	0.0168

TABLE 4

Thermal Conductivity of Ethane

TEMP. ° F.	PRESSURE ATM.	THERMAL CONDUCTIVITY B.t.u./(hr.)(sq.ft.)(° F./ft.)
107.5	1.0	0.0135
	8.5	0.0138
	18.0	0.0144
	24.0	0.0153
	30.3	0.0156
	34.3	0.0165
	39.1	0.0177
	43.0	0.0186
	46.0	0.0198
	49.5	0.0221
	52.6	0.0255
	55.1	0.0309
	56.6	0.0346
	58.3	0.0418
	61.1	0.0413
	64.4	0.0383
	69.0	0.0383
	77.4	0.0398
	88.7	0.0413
107.5	110.8	0.0461
	133.8	0.0496
	160.8	0.0534
	196.0	0.0542
134	1.0	0.0147
	8.9	0.0152
	17.0	0.0156
	24.0	0.0158
	30.2	0.0166
	32.7	0.0167
	37.9	0.0171
	43.1	0.0181
	49.3	0.0191
	52.7	0.0205
	56.1	0.0214
	58.7	0.0220
	61.1	0.0234
	63.2	0.0257
	68.4	0.0280
	76.1	0.0325
	86.0	0.0364
	111.3	0.0407
	136.4	0.0458
	162.6	0.0485
	178.3	0.0492
153	1.0	0.0159
	11.1	0.0164
	23.3	0.0172
	32.0	0.0179
	45.7	0.0196
	55.7	0.0215
	65.6	0.0242
	87.5	0.0315
	110.8	0.0365
	136.0	0.0400
	161.2	0.0430
	191.9	0.0453

vection is most probable. To determine whether convection was present, the pressure was adjusted to 60 atm. and a series of measurements was made in which the over-all temperature difference across the apparatus was varied from 4 to 16° F., maintaining the arithmetic average temperature of the gas constant. For this range of temperature differences the apparent thermal conductivity was constant within the experimental error. The measured values showed no definite increasing or decreasing trend. This indicates that the irregularity is due to a cause other than convection.

Figure 5 shows the thermal-conductivity ratio for ethane plotted vs. reduced pressure with the curved lines representing the values predicted by the general correlation shown in Figure 3. Experimental values of the thermal-conductivity ratio are considerably lower than the predicted values. Since measured viscosity and P-V-T data for ethane have been correlated reasonably well by means of the theorem of corresponding states, this anomalous behavior of the thermal conductivity was unexpected. In order to determine the reproducibility of the measurements at 107.5° F., they were repeated after moving the apparatus to a new location and recalibrating it. These more recent measurements are plotted along with the earlier data for comparison. The agreement between the two sets is within the expected experimental error. The irregularity in the curve near the critical density was also found to be reproducible. These are not entirely independent determinations as a measurement by another investigator using other apparatus would be. Also they do not determine the effect of impurities in the sample since gas was taken from the same cylinder for all the ethane runs.

One possible explanation of the sudden increase in the thermal conductivity of ethane in the neighborhood of the critical density is that there is a tendency to form clusters of molecules in this region. Maass (*8*) has observed that above the critical temperature, which was taken as the highest temperature at which the meniscus between the liquid and the gaseous phases disappears, there is a region in which two distinctly different densities exist simultaneously in the system. This has been attributed to the tendency of the molecules to form clusters in this region. There has been much discussion about the reliability of the experimental data in this region, but in general it has been observed that there is a range of several degrees, Centigrade, over which considerable irregularity exists. Since the average temperature of the ethane in the thermal conductivity measurements was about 9° C. above the critical temperature, it was thought that the irregular region would be avoided. The temperature of the cooler wall in the test annulus, though not known precisely, is at least 6° C. above the critical temperature. It is possible, however, that even if the irregular attractive forces between the molecules are not strong enough to cause a significant amount of clustering, they may still provide a mechanism for transferring energy in addition to that transferred by the collision of the molecules.

The large deviation of the experimental ethane data from the corresponding states correlation casts doubt on the validity of this theorem for correlating thermal conductivity. While ethane is only a single instance of such deviation, it indicates the need of further measurements on larger molecules to determine whether this behavior is general. Such a discrepancy for thermal conductivity alone is to be anticipated since it is more

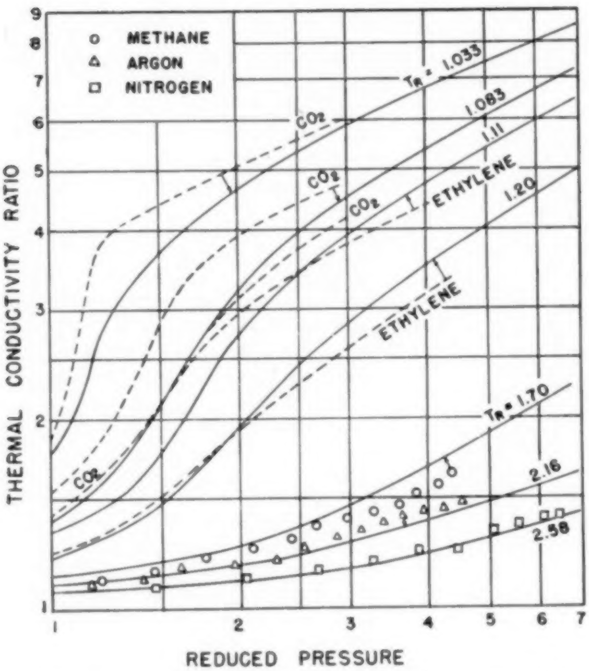


Fig. 1. Comparison of experimental results with Comings and Nathan correlation.

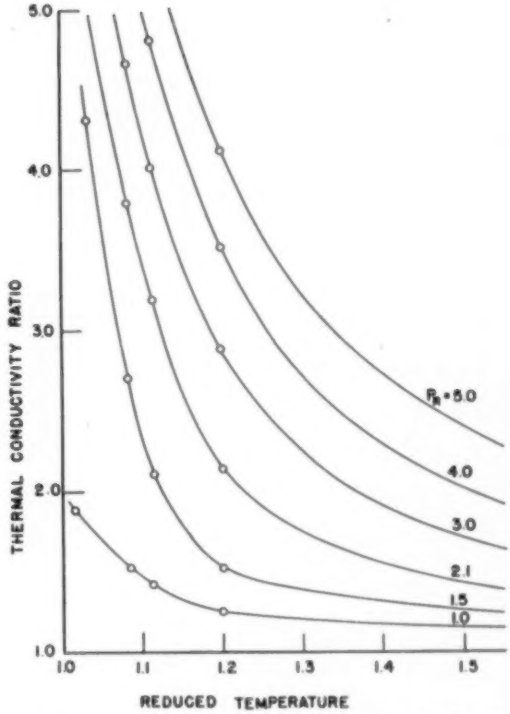


Fig. 2. Smoothed values of thermal conductivity ratio vs. reduced temperature.

sensitive to variations in the internal degrees of freedom of the molecules than any of the other properties which have been correlated in this manner.

Enskog's equation, on which the Comings and Nathan correlation is based, assumes that all the heat conducted by a gas is carried by the translational motion of spherically symmetrical molecules. The work of Pidduck (*6*) and Eucken (*2*), however, has shown that an appreciable portion of the thermal conductivity of a gas at atmospheric pressure may be attributed to the internal degrees of freedom of the molecules. Thus, in order to form a general correlation based upon Enskog's equation, it is necessary to assume that a constant fraction of the heat transferred is due to the internal energies of the molecules over the entire range of pressure considered.

There is no basis for this assumption although it appears to give fairly good results for the seven gases previously reported (*5*). It might be expected that the deviation would increase for molecules less like symmetrical spheres. Pidduck's equations show that the deviation of ethane may be accounted for by assuming that the portion of the heat transferred by rotation of the molecules is diminished considerably by the increase in pressure to 200 atm. It is conceivable that the increase in pressure inhibits the transfer of energy by the rotation of the molecules rather than increase it in the same proportion as the conductivity due to translation is increased. This effect would be even more pronounced if the molecules were crowded close enough together to prevent the free rotation of long molecules. Further measurements may confirm that the thermal conductivity of more complex molecules varies with change in pressure in a manner which differs from that of simpler molecules. This will indicate that the general correlations of thermal conductivity by Comings and Nathan, by Gamson, and the one presented in this paper are not reliable.

TABLE 5

Thermal Conductivity of Ethane at 107.7° F.

PRESSURE ATM.	THERMAL CONDUCTIVITY B.t.u./(hr.)(sq.ft.)(° F./ft.)
1.0	0.0142
11.4	0.0146
19.7	0.0152
28.0	0.0163
37.8	0.0179
42.7	0.0190
46.5	0.0204
50.7	0.0236
53.1	0.0256
55.9	0.0318
59.4	0.0413
63.7	0.0398
65.7	0.0396
70.2	0.0398
77.8	0.0405
88.4	0.0421
100.8	0.0448
114.2	0.0463
127.0	0.0477
139.2	0.0491
152.2	0.0500
172.3	0.0520
192.6	0.0554

Literature Cited

1. Comings, E. W., and M. F. Nathan, *Ind. Eng. Chem.*, **39**, 964 (1947).
2. Eucken, A., *Phys. Zeits.*, **14**, 324 (1913).
3. Gamson, B. W., *Chem. Eng. Progress*, **45**, 154 (1949).
4. Keyes, F. G., and D. J. Sandell, Jr., *Trans. Am. Soc. Mech. Engrs.*, **72**, 767 (1950).
5. Lenoir, J. M., and E. W. Comings, *Chem. Eng. Progress*, **47**, 223 (1951).
6. Pidduck, F. B., *Proc. Roy. Soc.* (London), **A101**, 101 (1922).
7. Sellschopp, W., *Forsch. Gebiete Ingenieurw.*, **5B**, 162 (1934).
8. Tapp, J. S., E. W. R. Steacie, and O. Maass, *Can. J. Research*, **9**, 217 (1933).
9. Vargaftik, N., *Tech. Phys. U.S.S.R.*, **4**, 343 (1937).

Discussion

Anonymous: What is the thermal conductivity of water vapor at high pressure? Has it been measured?

J. M. Lenoir: The thermal conductivity of water vapor at high pressure has been measured by Keyes and Sandell (*2*) or (*4*) of paper. No anomaly was observed. This may be because sufficiently high pressures

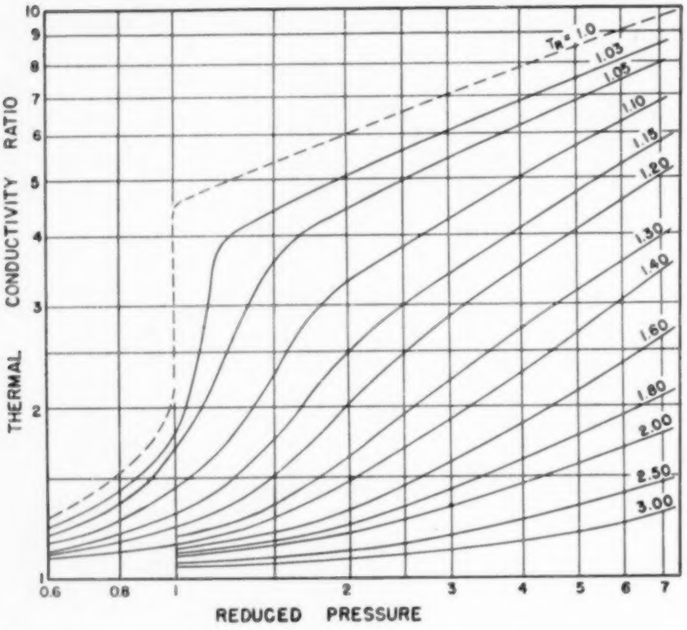


Fig. 3. Correlation of thermal conductivity ratio based on experimental measurements.

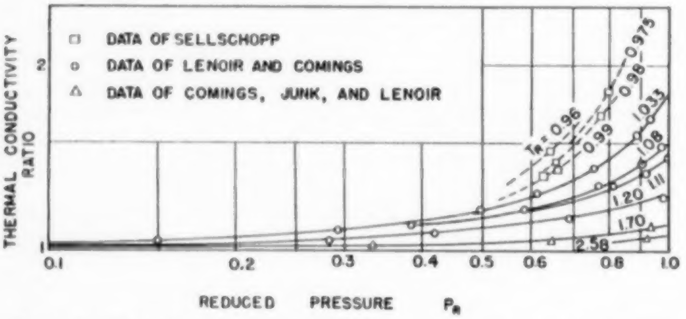


Fig. 4. Thermal conductivity ratio versus reduced pressure below the critical pressure.

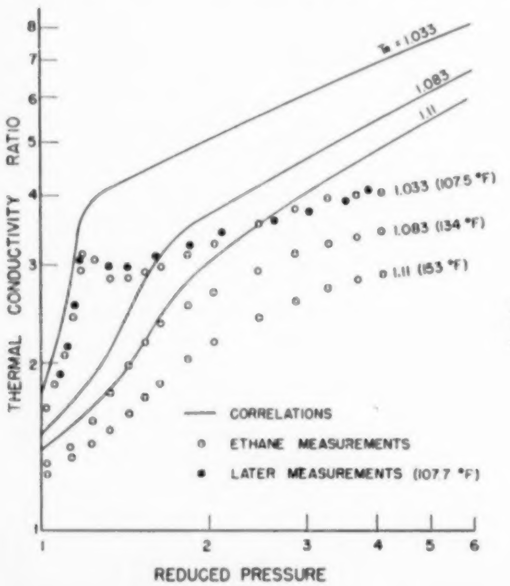


Fig. 5. Comparison of correlation of thermal conductivity ratio with the measured values for ethane.

were not reached or that since there is sufficient rigidity in the molecule, this peculiarity would not occur. After all, carbon dioxide is a complicated molecule, but we presume that its rigidity prevents this anomaly from occurring.

Anonymous: How do you allow for the effect of radiation by your method of measuring the conductivity of a gas?

J. M. Lenoir: The effect of radiation was covered in an earlier paper [see (*5*) of paper] and I don't want to go into it now except to say it has been shown to be of negligible effect. Since that time W. A. Junk (*1*), who has followed me in this work, has shown that even if there is appreciable radiation, the error is not significant. Radiation simply does not play a part in this apparatus.

B. F. Dodge (Yale University, New Haven, Conn.): It is radiation across the gap which is of concern, but what you mean is that it is so small as to be negligible. There is a temperature difference, of course.

J. M. Lenoir: The apparatus was fabricated with the walls of the gas layer gap so that they would have a small emissivity. With the extreme thinness of the gas layer, the heat-transfer rate by conduction is relatively high compared with the small radiation heat transfer. The low emissivity of the walls makes the fraction of heat transferred by radiation small. Even though the walls did not have a low emissivity, the same results would be obtained. The reason for this is that the calibration curve takes into account the radiation heat transfer and the measurements are valid, provided the emissivity of the walls does not change appreciably between the time the apparatus is calibrated and the measurements are made.

F. W. Preston (Pennsylvania State College, State College, Pa.): Do you feel that your correlation would predict the thermal conductivity of gaseous mixtures if molal average reduced temperature, and pressure were used as correlation parameters.

J. M. Lenoir: Yes, I think the correlation will work for gaseous mixtures if the mixture is a type that is not too complicated, and if the molecule is not too complicated so that you have internal degrees of freedom. I think there are also some other restrictions. With the recent work Keyes (*3*) has done on nitrogen-carbon dioxide mixtures, we should look on mixtures involving carbon dioxide with considerable caution and they probably could be expected not to fit the data.

Literature Cited

1. Junk, W. A., and E. W. Comings, *Chem. Eng. Progress*, **49**, 263 (1953).
2. Keyes, F. G., and D. J. Sandell, *Trans. Am. Soc. Mech. Engrs.*, **72**, 767 (1950).
3. Keyes, F. G., *Trans. Am. Soc. Mech. Engrs.*, **74**, 1303 (1952).

Presented at A.I.Ch.E. Forty-fifth annual meeting, Cleveland, Ohio.

Drying of Air in Fixed Beds

L. C. Eagleton and Harding Bliss Yale University, New Haven, Connecticut

The rate of drying of air in fixed beds of activated alumina, Florite, and silica gel was studied. Effluent concentration as a function of time was measured at several valves of inlet concentration, bed length, flow rate, and temperature. It was found that the rate governed by diffusion both through the air film and within the particles, and performance coefficients are given. These data are directly applicable for design purposes, if the input water content is below 0.003 lb. water/lb. air.

The drying of gases in fixed beds is a widely practiced operation in the chemical industry, and it is representative of the many fixed-bed problems which include ion exchange, heat transfer, and the closely related, but more general operation of adsorption. All these processes are characterized by the break-through phenomenon in which the material discharged from the bed remains at a low concentration (or temperature) for a considerable period and then rises to that value of the stream entering the bed. This rise, when plotted against time or cumulative material passed through the bed, exhibits a general *S*-shape. The particular shape and the horizontal displacement of this break-through curve are all important for design purposes and for understanding the fundamental mechanism. Despite the wide use of this method of gas drying, the data in the literature are surprisingly meager, particularly in the range of variables covered, and it was the authors' purpose, first to record and present such data; second, of course, the aim is to show how these data may be used for design purposes and to what extent they disclose information on the fundamental mechanism.

Scope

All runs were made with a drier of 0.628 in. I.D. The following independent variables, all of which were held as nearly constant as practicable for any one run, were studied over the ranges indicated:

Air rate: 33-520 lb./(hr.)(sq.ft.)
Temperatures: 80, 95, and 110° F.
Inlet water composition: 0.001-0.01 lb. H_2O/lb. air.
Bed weight: 0.02-0.18 lb.
Bed height: 0.16-1.75 ft.
Initial water content of solid (other than residual or bound water): zero, except for a few runs of a special nature.
Adsorbents: Activated alumina, Florite, and silica gel.
Particle-size range: 0.056-0.079 in.
Regeneration conditions: Alumina and Florite—more than 8 hr. at 400° F.
Silica gel—more than 8 hr. at 350° F.

L. C. Eagleton is associated with Rohm & Haas Co., Philadelphia, Pa.

No attempt was made to control the pressure in the drying bed. Therefore, the value required to overcome bed friction and flowmeter pressure drop was exerted, and at high flow rates this was as much as 150 mm. over atmospheric. In most cases, it was essentially atmospheric.

Apparatus, Procedure, and Materials

Air, stored in pressure cylinders, was throttled in a reducing valve to a glass-wool, carbon and alumina-filled filter and thence to two saturators. These saturators contained water (sometimes aqueous sodium hydroxide) to a depth of nearly 30 in. with contact promoted by stainless steel wool. The humidity of the air was adjusted and controlled according to the pressure in these saturators. The air then passed through a simple entrainment separator to a needle valve with which the rate of flow to the drier was controlled. The wet air was then introduced to the drying tube via a heating coil immersed in the same thermostat as the tube. The drier was made of ½-in. brass pipe, 12½ or 26 in. long. It was held vertical and had a wire-screen support for the adsorbent at the bottom. A thermocouple was provided at the discharge end of the bed for observing the gas temperature. Lines before and after the drier led to the dew-point meter with which the water content of the air was determined, and the line before the bed served as a by-pass for prerun periods. This instrument was the General Electric portable dew point potentiometer, described by Frank (*3*) and Stack (*8*).

In operation the wet air was by-passed until the rate and humidity were constant for 15 min. Then the air was sent downward through the drier and the run proper began. Recordings of dew point, effluent gas temperature, flowmeter differential, barometric pressure, and saturator pressure were made at frequent intervals. When the effluent dew point reached and remained at the influent value for a short period, the run was stopped. In certain runs in which equilibrium rather than rate data were sought, the watch over flow rate was relaxed, but the run was continued for several hours after inlet and outlet dew points were the same to insure equilibrium.

The dew-point meter was calibrated by measuring the dew point of air saturated with water vapor in a bath of known and constant temperature, *i.e.*, air of known dew point. Agreement was as follows:

Temperature of Saturation Bath	Measured Dew Point
33° F.	33 ± 1° F.
−18° F.	−18 ± 1° F.
−20° F.	−20 ± 2° F.
−109° F.	−100° F.

The instrument was notably poorer below about −25° F. than at higher temperatures, largely caused by the appearance of ice as the condensed phase. The presence of ice was confirmed by the change in reflectivity of the condensed phase and by the sluggishness of its response to temperature changes compared to the water phase. The sluggishness below about −25° F. impairs accuracy.

Alumina (Alcoa, Grade F 1), Florite (Floridin Co.) and silica gel (Davison) were screened to 0.056 to 0.079-in. size and regenerated as described in a previous section. They were stored in well-sealed-filter flasks. The losses of these materials on ignition at the start and at the end of the work were in agreement, indicating no appreciable moisture adsorption during storage. Samples were

weighed for introduction to the drying tube and again after each run to permit material balance. Properties of the adsorbents are given in Table 1.

Data

Data on the equilibrium and break-through runs are available in the dissertation of Eagleton (*1*). Equilibrium data are portrayed graphically in Figures 1 and 2 and the break-through data of a represenative run are presented in Table 2.

Interpretation and Utility of the Data

General.

The first factor which must be realized in considering a fixed-bed operation is the equilibrium or capacity requirement. A bed of a certain size has a fixed capacity for the adsorbate entering in the feed stream. In addition, the capacity of the adsorbent for smaller concentrations of adsorbate in the entering stream defines the shape of the equilibrium curve and is important in fixed-bed operation. For equilibrium curves concave toward the gas concentration axis (such as here in the region studied), the break-through curve would be a straight vertical line as in Figure 3*a*, if the rate processes for transfer from fluid to solid were infinitely fast, and if longitudinal diffusion were negligible. Then, finite rate processes diffuse the break-through curve so that it may appear as in Figure 3*b* or 3*c*. Equality of the shaded areas in these figures is obviously required by the material balance. The curve in 3*c* is typical of the ones observed in this work. That in 3*b* is a typical Schumann-Furnas (*4*) curve, and it is apparent that these data do not conform to such shape. The reasons are simple enough. The Schumann-Furnas curves are derived for a linear equilibrium. This analysis also requires that the rate process be proportional to the difference between a concentration at the gas-solid interface and the average or bulk concentration in the phase that is rate controlling (the film concept). Our system does not meet either the equilibrium or rate requirement. The latter point is supported by data on runs 33, F9 and S7 in which the bed was presaturated to an extent that the bed might be expected to operate in the nearly linear part of the isotherm. No Schumann-Furnas curve could be made to fit these data. In short, the long "tails" of the break-through curves point to a more complicated mechanism, indeed to solid diffusion as well as fluid diffusion.

One may think that it is possible to fit a Schumann-Furnas curve to the lower portion of a break-through curve of any sort, and indeed it is. But, such

TABLE 1.—PROPERTIES OF ADSORBENTS

0.056 to 0.079 in.

47% voids (liquid displacement)

	Surface Area[1] sq.ft./lb.bed	Loss on Ignition Regenerated Sample, %	Average Bed Density	True Solid Density, lb./cu.ft.
Alumina	7.54	7.1	51.2[2]	97
Florite	8.69	6.8	51.2	97
Silica gel	10.58	5.5	41.9	79

[1] Calculated for spheres of this size after a count of the number of particles of this size range in a given weight of material. Greater irregularity of shape results in a greater number of particles and hence a greater area for Florite.

[2] A different sample used in runs 1-11 was not included in average.

Additional details on these matters are described by Eagleton (*1*).

TABLE 2.—RUN 32

Adsorbent—Activated alumina
Particle size—0.056 to 0.079 in.
Bed diameter—0.628 in.
Bed height—9.84 in.
Increase in bed weight during run—2.174 g.

Bed temperature—79.95° F.
Bed pressure—766.1 mm. Hg
Flow rate—0.003585 lb. dry air/min.
Inlet concentration—0.00282 lb. H_2O/lb. air.

Time min.	Weight of Dry Air Downstream lb.	Exit Dew Point °F.	Exit Partial Pressure, H_2O mm. Hg.	c/c_o
416.5	1.494	−45	0.108	0.0314
420.0	1.505	−36	0.180	0.0523
422.0	1.515	−32	0.224	0.0651
424.2	1.521	−28	0.278	0.0808
426.7	1.529	−25	0.328	0.0954
428.2	1.535	−21	0.405	0.118
432.2	1.550	−13	0.608	0.177
437.0	1.566	− 7	0.812	0.236
442.5	1.586	+ 1	1.19	0.346
450.0	1.613	+ 8	1.64	0.477
457.4	1.640	+13	2.05	0.596
462.0	1.656	+16	2.35	0.684
469.8	1.684	+18¾	2.63	0.768
480.0	1.720	+20½	2.84	0.825
488.7	1.751	+21½	2.97	0.863
519.0	1.860	+22¾	3.12	0.907
553.0	1.982	+23	3.16	0.919
587.4	2.106	+24	3.31	0.963
691.0	2.478	+24½	3.37	0.980
855.0	3.064	+25	3.44	1.000
Inlet		+25	3.44	

TABLE 3.—EFFECT OF BED LENGTH ON ADSORPTION BAND WIDTH AT LOW INLET CONCENTRATION

Run	Inlet Concentration lb. water/lb. air	Bed Weight g.	Δy c/c_o from 0.1 to 0.8 lb. air
	At flow rate of 0.0094 lb.air/min.		
1	0.0023	9.1	0.30
2	0.0023	15.8	0.33
11	0.0026	40.5	0.29
13	0.0024	40.5	0.25
	At flow rate of 0.0036 lb.air/min.		
7	0.0024	20.4	0.23
14	0.0024	20.2	0.19
9	0.0025	40.5	0.24
19	0.0027	40.6	0.16
32	0.0028	40.5	0.18
23	0.0025	75.7	0.19
17	0.00100	20.2	0.27
16	0.00096	40.4	0.30
F5	0.0029	20.9	0.16
F2	0.0029	84.1	0.18
S1	0.0029	21.0	0.35
S2	0.0027	40.6	0.39
S3	0.0029	71.3	0.39

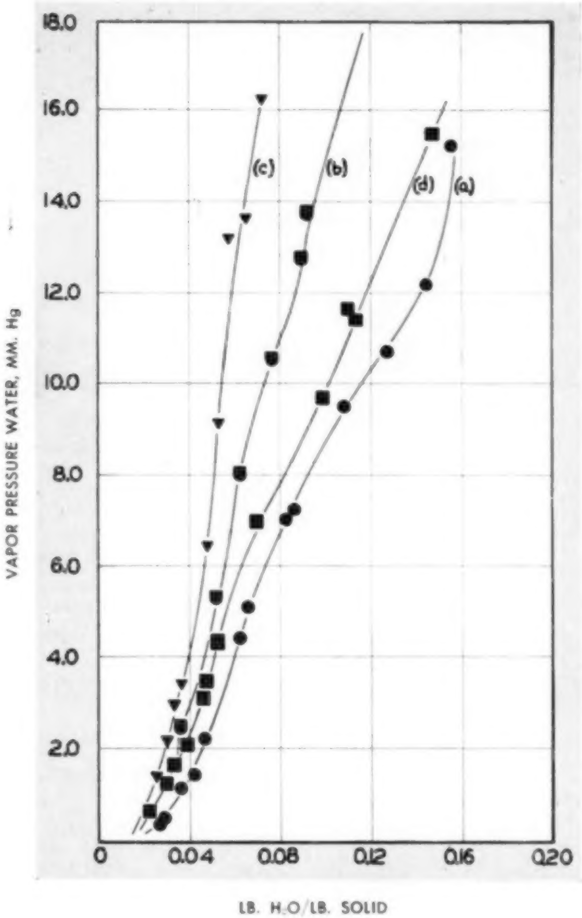


Fig. 1. Isotherms.

a. Activated alumina at 80° F.
b. Activated alumina at 95° F.
c. Activated alumina at 110° F.
d. Florite at 80° F.

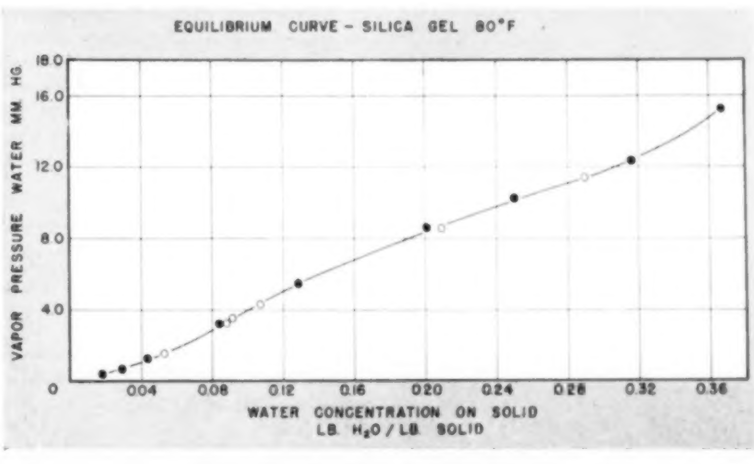


Fig. 2. Isotherm for silica gel.

a procedure does not meet the material balance requirement at all as Figure 3*d* shows. The only curve of this sort which satisfies the material balance is shown in Figure 3*e*, and the failure to match the kinetic behavior is apparent.

Constant Band Width for Low Concentration

When the equilibrium is concave toward the c-axis as shown in Figure 1, Gleuckhauf (*5*) has shown that this results in a self-sharpening tendency, that is, the band (measured in units of amount of fluid through the bed between arbitrary c_o values such as 0.1 and 0.8) tends to become less and less as it moves down the bed. This tendency is counterbalanced by finite rate processes, and the net result is a constancy of band width. This idea, which results in a great mathematical simplification, may be subjected to test by measuring the band width for various bed lengths. These results for low values of c_o are given in Table 3, and practical constancy of the band width is indicated.

It is evident in Table 3 that the band width, while influenced by c_o, flow rate, and nature of the adsorbent, is unaffected by bed length for any one combination of these other variables. It is also apparent that these band widths are small.

Design Method for Low Concentration Feed

This permits us to state the answer to one of our aims . . . the design question. If one wants to design a drier for these low values of c_o (about 0.003 lb. H_2O/lb. air and below), one has only to consider the band width as measured here a constant. A long commercial bed to perform this drying operation would permit the same band width, and for any practical bed the design should be made on the basis of attainment of practically the full capacity of the bed at breakthrough, or perhaps only 95% of it for conservative practice.

Velocity and entering concentration do affect the band width, as clear in Table 3, but for practical values of these variables the band width is constant and small, and the design method just described above should be satisfactory.

Interpretation

The proved constant band width makes it possible to derive an equation, taking into account rates of diffusion in fluid and solid phases (the latter considerably simplified), as follows. The assumptions are:

1. The adsorption zone is constant as it moves down the bed.

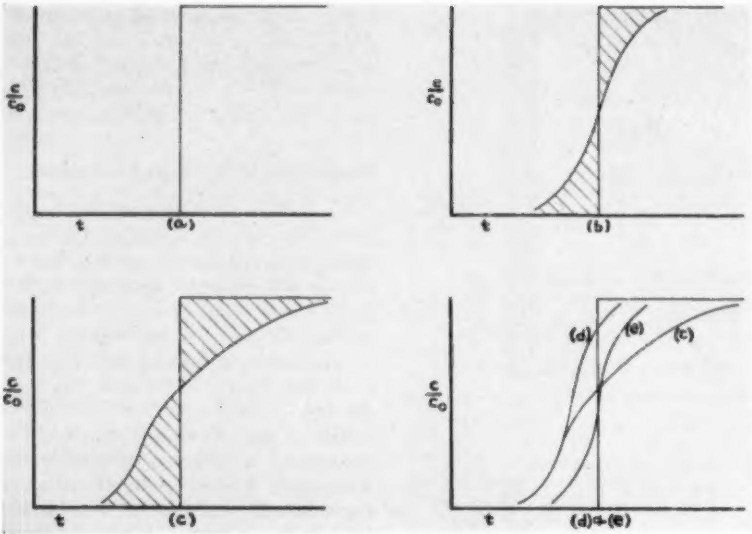


Fig. 3. Representative break-through curves.

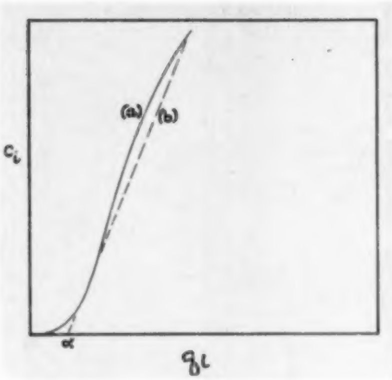


Fig. 4. Comparison between actual (a) and assumed (b) isotherms.

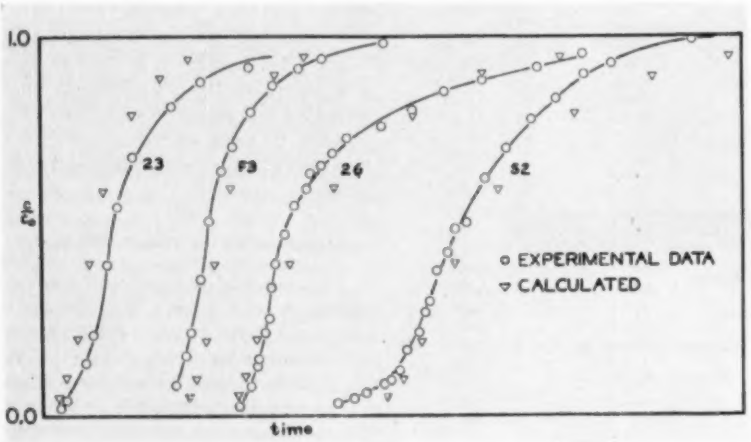


Fig. 5. Comparison of calculated and experimental break-through curves.

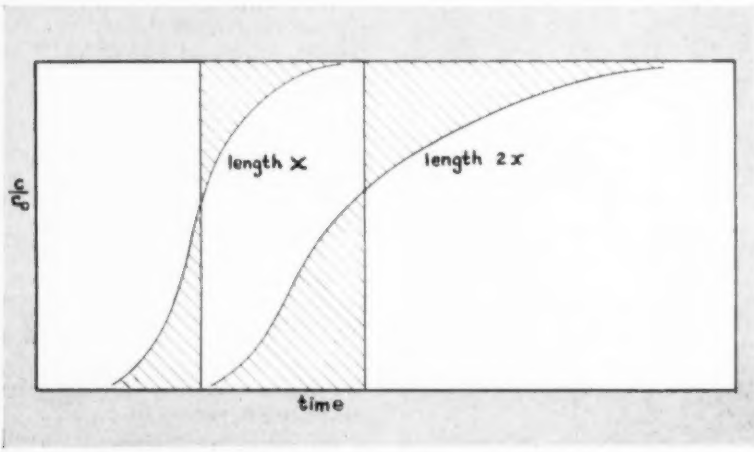


Fig. 6. Effect of bed length on shape of break-through curves at high values of c_o.

2. The isotherm which in truth is curved and concave toward the c-axis is of the following form which is also concave to the c-axis but made up of two straight lines

$$q_i = \alpha + \frac{a - \alpha}{c_o} c_i \quad \text{for } \alpha < q_i < a \tag{1}$$

and $c_i = 0$ for $0 < q_i < \alpha$

The equilibrium according to this assumption is sketched in Figure 4.

Values of α are:

0.025 alumina at 80° F.
0.014 alumina at 110° F.
0.022 alumina at 95° F.
0.020 Florite at 80° F.
0.20 silica gel at 80° F.

3. Rate equations are

$$\left(\frac{\partial q}{\partial t}\right)_x = k_g S(c - c_i) \tag{2}$$

$$= k_s S(q_i - q) \tag{3}$$

This simplification of the solid diffusion equation assumes a solid "film," which is probably not so extreme as it first appears because of the concentration of weight near the surface of a sphere. An exact mathematical solution of the solid diffusion equation with fluid diffusion in the unsteady state with a non-linear isotherm will probably be a long time coming.

4. No concentration, pressure, or temperature gradients perpendicular to the flow.

5. No interparticle diffusion or fluid diffusion in the direction of flow.

With these assumptions and the method of Gleuckhauf (5) these equations were derived:

for $c_D > c$

$$\ln \frac{c_D/c_o}{c/c_o} = -\frac{c_o k_g S y}{a V} + \frac{k_g S x}{V} + 2 - \frac{c_o}{c_D} \tag{4}$$

for $c > c_D$

$$\ln \frac{1 - c_D/c_o}{1 - c/c_o} = \left[\frac{c_D c_o}{1 - c_D/c_o}\right]\left[\frac{c_o k_g S y}{a V} - \frac{k_g S x}{V} - 2 + c_o/c_D\right] \tag{5}$$

in which

$$c_D = \frac{a}{a/c_o - r} \text{ and } r = -k_g S/k_c S$$

k_gS is obtained from Equation (4) by plotting $\ln c/c_o$ vs. y for low values of c/c_o and measuring the slope. With this value of k_gS, the slope of a plot of $\ln (1 - c/c_o)$ vs. y (Eq. (5)) gives c_D, thence r and k_cS.

These equations represent the behavior of all the runs at low values of c_o (below 0.003 lb. water/lb. air) for all velocities, temperature, and adsorbents studied. It is particularly interesting that it fits the data for high temperature runs so well where the constancy of band width was not studied. Figure 5 shows the agreement on runs 23, 26 (even though this was at $c_o = .01$), *F3* and *S2*. For compactness, the time scale is different for the different runs. Only comparison as to shape is possible. Table 4 summarizes the most important run conditions and the results of the application of these equations.

TABLE 4.—RUN CONDITIONS AND PRINCIPAL CALCULATED RESULTS

Run [1]	Bed Weight g.	Temperature °F.	Flow Rate [2] lb.air/(hr.)(sq.ft.)	Inlet Concentration lb.water/lb.air	Material Balance Error [3] %	lb.adsorbed/(hr.)(lb.bed)(lb.H_2O)/(lb.air) k_gS' [4]	k_cS' [4]
1	9.132	80.0	268.	0.00231	18.6	223.	30.
2	15.775	80.0	268.	0.00234	8.8	202.	11.3
7	20.359	80.0	100.0	0.00240	1.6	85.	2.6
9	40.479	80.0	100.0	0.00252	3.0	62.4	5.4
10	40.495	80.0	176.	0.00260	—2.1	115.	10.0
11	40.470	80.0	256.	0.00257	1.4	194.	8.0
12	40.425	80.0	53.8	0.00240	18.5	76.8	10.2
13	40.511	80.0	256.	0.00241	5.3	154.	15.0
14	20.186	80.0	100.0	0.00244	—4.6	97.	7.3
15	20.217	80.0	55.8	0.00240	0.6	60.0	11.0
16	40.411	80.0	100.0	0.000958	1.4	71.4	5.5
17	20.223	80.0	100.0	0.000998	8.1	78.4	5.8
18	20.196	80.0	256.	0.00120	....	153.	3.7
19	40.608	80.0	98.0	0.00272	5.5	88.	12.3
20	40.542	80.0	192.	0.00276	2.0	125.	10.6
21	20.230	80.0	33.6	0.00272	—1.2	77.2	6.2
22	40.595	80.0	518.	0.00280	5.5	355.	8.6
23	75.702	80.0	100.0	0.00254	3.9	112.	4.9
24	40.433	80.0	514.	0.00292	10.6	283.	14.1
25	20.171	80.0	33.5	0.00276	8.0	55.9	19.
26	20.159	80.0	100.5	0.00986	—1.1	131.	8.0
27	40.442	80.0	51.4	0.00880	4.6	109.	3.1
28	40.471	80.0	276.	0.00932	6.4	275.	12.7
29	40.377	80.0	100.0	0.01010	5.9	107.	6.5
30	77.410	80.0	100.0	0.01010	5.7	149.	3.3
31	79.256	80.0	50.2	0.01002	2.5	101.	1.43
32	40.464	80.0	100.0	0.00282	2.5	117.	4.1
33	42.638	80.0	100.0	0.00788	5.2	.....	....
36	20.812	110.2	35.2	0.00195	6.4	75.1	3.6
37	40.413	110.2	271.	0.00240	4.5	178.	18.3
38	40.587	110.2	35.1	0.01122	6.3	75.2	4.9
39	41.184	110.2	272.	0.01044	6.0	255.	19.1
40	40.379	94.8	34.4	0.01060	—4.2	85.	2.8
41	40.720	94.8	271.	0.01062	5.2	249.	11.7
42	40.668	94.8	271.	0.00213	7.8	254.	6.3
43	20.767	94.8	34.8	0.00191	....	74.2	3.7
44	40.027	94.8	272.	0.00185	8.3	212.	9.7
F1	20.700	80.0	100.0	0.00285	9.6	85.	8.0
F2	84.126	80.0	101.0	0.00294	4.9	84.	4.0
F3	25.013	80.0	35.2	0.00262	1.5	67.2	6.5
F4	20.884	80.0	101.5	0.00300	—2.5	83.	7.4
F5	20.876	80.0	101.0	0.00287	5.8	86.	9.2
F6	40.996	80.0	507.	0.00282	9.7	276.	18.5
F7	40.501	80.0	101.5	0.00948	5.4	80.	7.5
F8	21.121	80.0	100.0	0.00139	1.1	68.8	4.8
F9	21.833	80.0	100.0	0.00940	1.5	.....	....
S1	20.983	80.0	100.0	0.00285	6.2	84.	....
S2	40.648	80.0	95.5	0.00267	5.0	50.8	....
S3	71.316	80.0	100.5	0.00294	—2.5	83.	10.4
S4	20.487	80.0	35.2	0.00259	7.1	36.8	....
S5	40.983	80.0	508.	0.00298	—0.9	216.	19.3
S6	20.7[illegible]5	80.0	102.0	0.00124	7.1	71.5	15.0
S7	21.838	80.0	102.0	0.00706	—0.4	.....	....
S8	40.754	80.0	101.0	0.00934	2.5	112.	....

[1] Runs 1-44 alumina, F for Florite, S for silica gel.

[2] Based on full cross-section of drier.

[3] (Actual gain in weight)—(calculated gain from integrated curve) divided by (actual weight gain).

[4] Primes refer to the area correction factor applied to Florite and silica gel to bring them to the same area as alumina. See Table 1.

Plots of k_gS and k_sS show considerable dispersion due to experimental error, but such plots yield correlation equations as follows:

Activated alumina and Florite	$k_gS' = 9.3G^{0.55}$
Silica gel	$k_gS' = 6.3G^{0.55}$
All three	$k_sS' = 7.3$

in which G is in lb./(sq.ft.). The above values can be used in Equations (4) and (5) for alumina, but they must be multiplied by 7.54/8.69 for Florite and 7.54/10.58 for silica gel because of the differences in surface area as indicated in Table 1.

The values of the coefficients k_gS for alumina and Florite have been used for calculations of the J-factor as suggested by Ergun (2) and plotted against Reynolds number divided by $(1-\epsilon)$. The values of J here are about 25% below those from the data of Resnick and White (7) and 50% below the data of Hurt (6).

This method of kinetic interpretation is recommended as a basis for design even if the operating conditions differ somewhat from those studied here, provided c_o is low. For very similar operating conditions, the measured band widths should suffice for design purposes, as above described.

High Concentration Runs

The above observations do not apply to runs of high inlet concentration, since here the band width is not constant. The higher concentration has accelerated the fluid diffusion rate to such an extent that the solid diffusion predominates and this diffuses the band greatly. Also, the linear portion of the isotherm at higher concentrations exhibits no self-sharpening properties, and the band would diffuse with any finite rate of adsorption. This effect for two lengths is shown in Figure 6.

As the diffusion tail is lengthened it must push the break-through point back a great deal, and the bed-utilization may be much reduced as length is increased to commercial values. There is no quantitative interpretation of these results. Since the c_o is still well within a range of practical interest, much about drying remains to be learned.

Conclusion

This work shows that the phenomenon of drying in fixed beds is influenced by both fluid and solid diffusion. For concentrations of 0.003 lb. H_2O/lb. air and below in the influent (80-110° F., 1 atm.), the band width is constant and small, and as a consequence of this a commercial-size bed can be designed by assuming about 95% of equilibrium utilization of the bed at break-through.

A kinetic interpretation is presented which supports the contention that both fluid and solid diffusion rates are important, and it correlates the data here very well.

Influent concentrations of 0.01 lb. H_2O/lb. air are not explained or correlated in this manner. The band diffuses rapidly and further work will be required to explain results in this range.

Acknowledgment

The authors acknowledge the financial assistance of the Research Corporation in carrying out this study, and the help rendered by Charles A. Walker.

Notation

- a = capacity of solid in equilibrium with gas of concentration c_o, lb. H_2O/lb. solid
- c = concentration of water in air, lb. H_2O/lb. air
- c_D = concentration in air at point of discontinuity, lb. H_2O/lb. air
- c_i = concentration in air at gas-solid interface, lb. H_2O/lb. air
- c_o = inlet gas concentration, lb. H_2O/lb. air
- G = air flow rate based on free bed cross section, lb./(hr.)(sq.ft.)
- J = mass-transfer factor
- k_g = gas-film transfer coefficient, $\dfrac{\text{lb. adsorbed}}{(\text{hr.})(\text{sq.ft.})\left(\dfrac{\text{lb. } H_2O}{\text{lb. air}}\right)}$
- k_s = solid-film transfer coefficient, $\dfrac{\text{lb. adsorbed}}{(\text{hr.})(\text{sq.ft.})\left(\dfrac{\text{lb. } H_2O}{\text{lb. solid}}\right)}$
- q = average concentration of adsorbate in solid particles, lb. H_2O/lb. solid
- q_i = concentration in solid at gas-solid interface, lb. H_2O/lb. solid
- r = $-k_gS/k_sS$
- S = surface area of particles, sq.ft./lb. solid
- S' = surface area for activated alumina, sq.ft./lb. solid. Used with k_g or k_s as follows: $k_gS = k_gS'$ for activated alumina; k_gS times S for activated alumina/S for solid in question = k_gS' for solid (Florite or silica gel).
- t = time, hr.
- V = air rate, lb./hr.
- x = weight of bed, lb.
- y = $Vt - mx$, lb. air downstream, lb.
- α = constant
- ϵ = fraction voids

Literature Cited

1. Eagleton, L. C., "Drying of Air in Fixed Beds," Dissertation, Yale School of Engineering (1951).
2. Ergun, S., Chem. Eng. Progress, **48**, No. 6, 227 (1952).
3. Frank, H. K., Gen. Elec. Rev., **41**, 435 (1938).
4. Furnas, C. C., Trans. Am. Inst. Chem. Engrs., **24**, 142 (1930).
5. Gleuckhauf, E., J. Chem. Soc., **149**, 1302 (1947).
6. Hurt, D. M., Ind. Eng. Chem., **35**, 522 (1943).
7. Resnick, W., and R. R. White, Chem. Eng. Progress, **45**, No. 6, 377 (1949).
8. Stack, S. S., Gen. Elec. Rev., **41**, 106 (1938).

Discussion

R. L. Costa (Mutual Chemical Co. of America, Baltimore 31, Md.): Is that type of data not extremely close to, if not exactly the same as, that which can be applied to a single solute system in ion exchange?

L. C. Eagleton: That is true. If the ion-exchange equilibrium is very favorable and not linear, the mathematics is identical. Some work on ion exchange has indicated that the rate of diffusion inside the particle is not as important as it was in this case. For those instances, the solution is slightly easier by having only the one rate equation—the one for the diffusion through the fluid only.

D. J. Kridel (Eastman Kodak Co., Rochester, N. Y.): In the correlation you showed of kgs and your decision to use the average value, did you examine that from the point of view of trying to determine the correlation coefficient or anything of that kind?

L. C. Eagleton: We did not. The reason was that there were fewer points on the extremes of the line than there were in the center and we thought that we did not have enough data to do that consistently.

O. E. Dwyer (Brookhaven National Lab., Upton, L. I., N. Y.): You might have gotten a better correlation if you had considered variations in concentration. We know that in gas transfer the coefficient varies with the concentration of the diffusing components in the gaseous film.

L. C. Eagleton: It was our opinion that on theoretical lines the gas-film coefficients would not change with concentration because the diffusivity does not change with concentration. Did you mean that on theoretical grounds you would expect it to change with concentration?

O. E. Dwyer: Diffusivity is just one factor in determining the coefficient.

L. C. Eagleton: That is true. The film thickness is also one. Of course, the inerts are high. The amount of water is small in these runs so that it is not a case of concentrated gas diffusing. We could easily put in a correlation of the small change observed experimentally and it would be all right, but, in view of the scattering of the data, we decided this refinement was not justified. It added a complication for a small gain in accuracy of predicting a break-through.

Presented at A.I.Ch.E. Rochester meeting

THE PURPOSE STATED

The rather sudden development of modern statistical methods confronts the chemical engineer with an opportunity and with a problem—the opportunity, that of increasing the precision and the validity of planned experiments, whether run in laboratories, in pilot plants, or in full-scale equipment, and the problem, that a new and unfamiliar set of ideas has to be mastered for which the engineer finds himself ill prepared.

Dating the start of modern statistics from 1908, when a chemist, W. S. Gossett, published a paper on the probable error of a mean, it is no simplification to attribute the major part of the development since that time to R. A. Fisher and his school. These men worked in experimental agriculture and in genetics, yet the methods they developed and the principles they discovered hold when the following two conditions obtain: (1) It is desired to measure the simultaneous impact of a number of factors. (Present statistical methods appear to be applicable to the study of from two to sixteen factors.), and (2) Repeated experiments, or tests, or runs, under conditions as nearly constant as possible, do not give identical results. Put this way, some engineers would say that practically all problems are statistical ones. It does not follow that all problems can be attacked by the statistical methods currently available.

The four papers presented in Cleveland at an A.I.Ch.E. Symposium on Statistical Methods give three broad classes of problems where it seems profitable to apply statistical methods. In this issue W. J. Youden's paper shows how to make efficient comparisons of a considerable number of "treatments," or conditions, or varieties. In a succeeding issue K. A. Brownlee's paper demonstrates how to judge the simultaneous impact of a number of factors, when it is important to know whether or not each factor produces the same effect when the other factors are varied. The paper by V. W. Vaurio and C. Daniel covers a class of problems in which it is desired to appraise the simultaneous effects of two kinds of factors. The first kind of factor has definitely determined levels and produces effects that are constant for each level. The second kind of factor can be sampled only at random, and it produces only "scatter"; it is this scatter which is to be measured. The concluding article, by H. Scheffé, gives the mathematical background required for making the judgments desired in the preceding paper.

Three words—*probability*, *orthogonality* (or balance) and *randomness*—summarize the ideas that are new to the engineer. The word probability is used most often in these articles to refer to the relative frequency of making the error of judging an effect to be due to a named factor, when in fact it is due to chance fluctuations. The idea of orthogonality is basic to all four papers. Its presence for example, permits each measurement in the Vaurio-Daniel paper to be used twenty-two times, each time in a different way.

CUTHBERT DANIEL, *Chairman*

Making One Measurement Do the Work of Two

W. J. Youden and W. S. Connor National Bureau of Standards, Washington, D. C.

Frequently measurements are made under conditions which are either hard to specify precisely or difficult to hold constant for any considerable period. Corrections for drifts or shifts arising from these uncontrolled conditions are often based on measurements made upon control or standard samples periodically introduced in the work schedule. These standard samples make possible the adjustment of the measurements on the test samples at the price of diverting effort that might otherwise be spent on test samples. The standard samples may be dispensed with by picking out certain ones of the test samples for measurement at a later time. This paper presents some schedules for the selection of test samples for remeasurement. When the schedule possesses a balanced symmetry the arithmetical operations for adjusting the observations become simple and easy. Furthermore, all the measurements made contribute information on the test sample.

Engineers expend much effort to effect improvements in the reliability of their measurements. As a result remarkable advances in the sensitivity and performance of instruments have been achieved. More attention has been given to the careful specification and control of external factors which may influence the results obtained with these better instruments. The objective has been to reduce the uncontrolled residual variation in measurements to the point where it would be of minor importance; and even to achieve a state of affairs where such chance variations in measurements could be altogether ignored. It turns out that it is an unending struggle because engineers put ever increasing demands upon their measurements. In a competitive world small effects may have large economic consequences. Furthermore, scientific discoveries sometimes depend upon the detection of differences of small magnitude.

It is worthwhile to consider what sort of success can be achieved by the control of disturbing external factors. One must first ascertain what factors are operating in this manner. Complete enumeration of them is not easy and the search often ends when further improvement appears to require an undue amount of

work. When factors have been identified, it is sometimes evident that the necessary control is costly and tedious. A common factor is temperature. In consequence there exists a variety of devices for controlling temperature. Alternatively, if the temperature is not controlled, it is recorded and an appropriate adjustment made to the measurement. Almost invariably the measurements are still influenced by factors not specified of imperfectly controlled or not allowed for. That this is so is demonstrated by the universal experience that two measurements will show better agreement when they are made in the same laboratory than when each of two laboratories reports one measurement.

Of course, there is no substitute for this tracking down of factors that disturb the measurements. It is necessary to get results that others can verify. But even today it comes as something of a shock to observe how much variation there is between laboratories when judged by the reproducibility of results within a laboratory. This has stimulated the undertaking of large-scale and costly interlaboratory studies. Far too often the study only confirms what one already knew, namely, that the laboratories disagree. The studies do not point the way to the elimination of the disagreement.

Again, in the reduction of variation to the point where it does not obscure the small differences of importance to the investigator, the growth of interest in statistical techniques probably reflects a reluctant awareness that it will not be possible to eliminate variation in measurements. Statistical methods of interpretation appear to many as a way of living with this variation and making the best of it.

Within Laboratory Experiences

Most researches are carried out in a given laboratory. At this stage it is, as a rule, not necessary to be concerned about the between-laboratory disagreements in absolute values. Usually the series of results obtained in a particular investigation are to be compared with one another. Relative precision is all that is required. Presumably a sister laboratory that is known to get high results would obtain a similar series all displaced on the high side and would draw the same conclusions. What may be overlooked is the existence of subdivisions within a laboratory that produce the same sort of disturbing influence found between laboratories. These subdivisions may be of many kinds, such as different operators, machines, days, batches of reagent. Even when it is recognized that such subdivisions contribute to the variation in the measurements nothing may be done about it. The reason is that the series of measurements is often too long to make feasible the obtaining of them in one time period with one operator on one machine, using one homogeneous lot of material. If the investigation involved only two or three, or some other small number it might be convenient to hold many or even all of the above factors constant and secure for the intercomparison of this small set a high precision. There is now available an extensive array of schemes that extend to large sets the high precision associated with small sets of measurements. Statisticians refer to such schemes as experimental designs.

Long before statisticians began to explore the subject of experimental design, scientists in certain circumstances made use of its basic idea. The situation that virtually forced an experimenter to use the idea usually arose when circumstances beyond his control provided him with an extremely limited quantity of homogeneous material. An additional supply would differ markedly from the first supply. Experimenters learned, how long ago no one knows, that the thing to do was to run a control measurement on each of the several lots of material and express the test results in terms of the control. An example exists in exposure tests with paints. It is known that the performance of a paint is greatly influenced by the character of the surface to which it is applied. If the substratum is not uniform for all tests, then differences will be ascribed to the paints that are, in reality, due to the substratum. A common test surface is wood, supplied by nature, and subject to all of nature's vagaries. Neither are there any obvious tests to satisfy the investigators that various pieces of wood are equivalent for the purposes of the exposure test. The experimenter falls back on a reasonable assumption, i.e., that two adjacent pieces cut from the same board would be as much alike as possible. The device employed is simple. The experimenter takes as many pieces of board as there are paints to compare and cuts each board in two pieces keeping track of their identity. A control or standard paint is applied to one-half piece from each board and the various test paints allotted to the remaining half, somewhat as shown.

BOARD

1	2	3	4	5
S	S	S	S	S
A	B	C	D	E

Obviously the comparison of any test paint, say D, with its standard or control gives the best chance of a fair comparison. If the 10 half-pieces had been mixed up and 5 painted with S and 5 with the other paints there would be no way to match up like halves. It is quite conceivable, that the variation shown among the 5 pieces painted with S in the scheme shown, exceeds the actual differences among paints A through E. This does not matter as long as each paint is judged against its own standard. Clearly the success of this scheme depends upon its being possible to show that, if the two halves from one board are painted with S, the results agree much better than when the pieces come from different boards. Presumably this must have been shown or half the exposure facilities would not be expended on the standard paint.

The performance of each paint may be expressed as a per cent of the control from the same board and then these figures used to rate the paints. Alternatively, the *difference* between the results for each paint and its own standard could be taken and applied to the average of all five results obtained with the standard pieces. This might be more useful, as the average for the standard so obtained should give a fair idea of what might be the life of the paint on an "average" board.

If five boards are used only one piece of board has received a given test paint, and it might be well to use ten or fifteen boards instead of five. Smaller differences between the paints will be detectable if the average of two or three test results can be used.

The employment of a control paint has overcome the diversity shown by different pieces of board but at a heavy price of using up half the test boards with the control paint. There is an alternate way of setting up a "control" that was used at least thirty-five years ago in another connection. The painting schedule is changed. First, all possible pairings of the letters S A B C D E are formed. There are 15 different pairs and these are assigned to 15 test boards as shown.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
S	S	S	S	S	A	A	A	A	B	B	B	C	C	D
A	B	C	D	E	B	C	D	E	C	D	E	D	E	E

There is an immediate consequence of this revised arrangement. The 15 test boards make available 5 pieces for each of the test paints and the control paint. The preceding scheme, with the use of 15 boards, would have provided *three* pieces for each test paint and 15 control pieces. The three pieces for a given paint would have been compared with

the three corresponding control pieces.

The problem is to set up a suitable control for the revised arrangement. One can consider test paint A, tested on boards 1, 6, 7, 8, and 9, and paint B tested on boards 2, 6, 10, 11, and 12. The following comparisons are set up:

Board	1	$A - S = d_1$
"	6	$A - B = d_6$
"	7	$A - C = d_7$
"	8	$A - D = d_8$
"	9	$A - E = d_9$

Total $5A - (S + B + C + D + E) = \Sigma d_a$

Board	2	$B - S = d_2$
"	6	$B - A = d_6$
"	10	$B - C = d_{10}$
"	11	$B - D = d_{11}$
"	12	$B - E = d_{12}$

$5B - (S + A + C + D + E) = \Sigma d_b$

It should be noted that A is compared with a "composite control," consisting of S, B, C, D, and E, while B is matched against a "composite control" consisting of S, A, C, D, and E. These "composite controls" are unfortunately not identical as they must be if they are to serve as a go-between. It is, however, easy to bring the two controls into agreement. If there had been a board, both ends of which had been painted with A, the difference between the ends should be zero. That is, A is equal to A. If to

$$5A - (S + B + C + D + E) = \Sigma d_a$$

there is added

$$A - A = 0$$

the result is

$$6A - \underbrace{(S + A + B + C + D + E)}_{\text{composite control}} = \Sigma d_a$$

The composite control is made to include all six paints.

A similar operation for paint B yields

$$6B - \underbrace{(S + A + B + C + D + E)}_{\text{composite control}} = \Sigma d_b$$

The same procedure is followed for paints S, C, D, and E, all of which give an expression with the same composite control. The appropriate Σd, when divided by 6, gives for each paint the difference between the paint and the average of the composite control.. These average differences, which incidentally are based upon *five* test pieces instead of three, serve to rank the six paints. It was suggested previously that, when *S* was the control, the average difference between a paint and its matched control could be added to or subtracted from the average of all the control pieces. Equally here, the obvious value to use for the composite control is the average of all 30 results, i.e., the five pieces available for all six paints.

If there is any hesitancy in adopting this synthetic control as a reference value one may, if one desires, compare any paint A with the control S by taking $1/6(\Sigma d_a - \Sigma d_s)$. The composite control, whatever its value, drops out of the picture. This average difference may be applied to the average of the absolute values for S obtained from the five pieces painted with S. The various paints may thus still be expressed in terms of the performance of the standard. If the purpose is merely to rate the test paints among themselves then S may be omitted altogether. Ten boards would then suffice and provide four test pieces for each paint, instead of two when ten boards are used with a single control.

This example with the test boards illustrates a general situation. Whenever there are unknown factors, or factors that are difficult to evaluate and control, recourse may be had to this device of picking some small area and assuming that these disturbing factors operate in the same way over that area. Test results obtained within this small area are presumed to be equally influenced by these unknown factors. The effects of these unknown factors drop out in the comparisons. The term *area* is used in a generalized sense. The experimenter has the responsibility to define the limits of the area within which comparisons may be advantageously made. The existence of such homogeneous areas is the indispensable condition for the profitable use of most experimental designs. A growing body of evidence provides testimony that such homogeneous areas do exist in the majority of experimental programs.

Single vs. Composite Control

Much work has been done in recent years to determine the most advantageous way of assigning the test items to the homogeneous area All the ways can be resolved into one or another manner of picking out the pairs to be formed. Use of a single control, assigned invariably to a part of each area is the most primitive and least efficient manner. There are, however, some other considerations of importance. For example, ten paints, by the single control system, require only ten boards, whereas the composite control system calls for forty-five boards. But the ten boards with the single control make no provision for estimating the precision of the comparisons. If the set is repeated, using twenty boards in all, then the precision of the comparisons may be computed. This is still fewer than 45. The forty-five boards will, of course, give a much better experiment and also give a good estimate of the precision, but there will be objection to such an increase in the size of the program.

The attractiveness of the composite control arrangement would be much enhanced if the requirement for a complete set of all possible pairs could be relaxed. Such is the case. For example, with ten paints, instead of forty-five pairs 15, 25, or 30 may be selected. The 15 pairs cannot be any chance selection but must fulfill certain requirements of symmetry. The following 15 pairs link the letters together, either directly or indirectly.

AH	BF	CE	DE	EJ
AI	BG	CG	DF	FI
AJ	BJ	CI	DH	GH

Each letter, such as A, occurs three times and is paired with just three other letters, as H, I, and J. These three other letters, it turns out, are also paired with the remaining six letters, as JB, IC, HD, JE, IF, HG. To put it another way: let the 10 letters represent football teams. Pick a team. This team plays three other teams. These three other teams meet the six teams that did not play directly with the team first picked. Short of each team playing all other nine teams, which would be a heavy schedule, the above-mentioned scheme provides a satisfactory basis for rating the teams.

The same composite control can be set up for this selection of pairs but a little more algebraic maneuvering is required. The goal is to set up, by using *differences* obtained from the pairs, a comparison between a given letter and a composite control made up of a complete set of letters. This may be done for the letter B by adding up the following pairings:

$3(B - F)$
$3(B - G)$
$3(B - J)$
$F - D$
$F - I$
$G - C$
$G - H$
$J - A$
$J - E$

and, of course,

$B - B$

Resulting in

$$10B - \underbrace{(A + B + C + D + E + F + G + H + I + J)}_{\text{composite control}} = \Sigma d_b$$

The factor of 3 for the first three differences was determined by inspection. It gave the desired composition for the control. This really amounts to a system of weighting. In comparing a given letter with a composite control more weight should be given to the letters met directly than to the letters met indirectly through the services of the intermediaries.

Now the total number of boards for the ten paints has been reduced to 15, and an estimate of precision is still available. Three test boards have been used for each paint. To get three boards for each paint with the single control system 30, or twice as many, boards would be required.

Picking a subset of 15 pairs from the complete set of 45 pairs leaves 30 pairs unused. These 30 pairs, too, as might be guessed, possess the necessary symmetry to make possible setting up a composite control. Thirty boards would be needed and these would provide six pieces for each paint. Still another way of picking pairs which works for all numbers is to write half the letters at the head of a series of columns and the remaining letters at the left of a series of rows. The required pairs are given by the intersection of the rows and columns. Ten letters give the following arrangement.

	A	B	C	D	E
F	.	.	.	.	.
G	.	.	.	.	.
H	.	.	.	.	.
I	.	.	.	.	.
J	.	.	.	.	.

If there were nine letters the last row is omitted. The pairs are AF, AG, AH, AI, AJ, BF, BG, and so on. It is apparent that when A and B are compared F, G, H, I, J all serve as controls because A and B have each met these five letters. The pairs thus selected do make it possible to set up as before a composite control and use the test material previously expended on a single control for additional measurements on the items under test.

The discussion thus far has been carried on as if the homogeneous area was sufficient to accommodate two, and only two, experimental items. Often three, four, five or more units constitute a natural area or block. A piece of wood might be sawed lengthwise and the resulting pieces then sawed in half. The four quarter pieces of the original piece of wood may be considered much alike. Single controls are often used in such cases. Indeed, the larger block cuts down the proportion of work expended on the control item. There is a great gain also for the method of composite controls, because, each squad or block sets up a considerable number of the required pairings. If the blocks contain four items then six pairs per block are immediately obtained. An example of how this may work out is afforded by the assignment of ten paints in sets of four to five pieces of wood cut into quarters.

1	2	3	4	5
A B	A E	B E	C F	D G
C D	F G	H I	H J	I J

There are six pairs per square, 30 pairs in all. A check will satisfy the reader that these 30 pairs are exactly the 30 pairs left over when the 15 pairs previously discussed, were picked from the complete set of 45 pairs which can be formed from the ten letters. It has already been stated that the residual 30 pairs are readily grouped so that the composite control can be set up for each of the letters. The five original pieces of wood have provided two test pieces for each letter, so that the number of test pieces (20) is even fewer than the 30 test pieces required to form just 15 pairs when the area accommodates only two paints.

The same 30 pairings can also be set up by using ten blocks each of which accommodates three items.

1	2	3	4	5
A	B	C	D	E
B	E	J	A	F
C	H	D	G	A
6	**7**	**8**	**9**	**10**
F	G	H	I	J
G	I	C	D	H
J	E	F	B	I

The Effective Basic Principle

The intention at this time is not to provide a catalog of such arrangements. Rather, the desire is to show how a basic principle, long employed in scientific work, has undergone some elaboration with an obvious gain in effectiveness. Less than twenty years ago Yates (*5*) wrote the initial theoretical paper in this field. Much of the important development of the theory of these arrangements is due to Bose (*1*, *2*). The earlier arrangements put little stress on holding to a minimum the number of tests pieces, chiefly because it was thought that the major field of application would be in agriculture. There are two recent books on the design of experiments (*3* and *4*). An elementary introduction is also available (*6*).

These arrangements are not an academic pastime. They are useful in the comparison of standard meter bars, Weston standard cells, temperature standards, and radio-activity standards. Such examples show that these arrangements are not limited to relatively crude measurements as may be the case in exposure tests. The utility of the device of a composite control is probably limited only by the ingenuity of the experimenters in recognizing areas of homogeneity in their operations and their taking advantage of the increase in precision that such areas make possible..

Literature Cited

1. Bose, R. C., and K. R. Nair, *Sankhya*, **4**, 337 (1939).
2. Bose, R. C., and T. Shimamoto, *J. Am. Stat. Assoc.*, **47**, 151 (1952).
3. Cochran, W. G., and G. M. Cox, "Experimental Designs," John Wiley & Sons, Inc., New York (1950).
4. Kempthorne, Oscar, "The Design and Analysis of Experiments," John Wiley & Sons, Inc., New York (1952).
5. Yates, F., *J. Agr. Sci.*, **26**, 424 (1936).
6. Youden, W. J., "Statistical Methods for Chemists," John Wiley & Sons, Inc., New York (1951).

Presented at A.I.Ch.E. Forty-fifth annual meeting, Cleveland, Ohio.

Errata

In the article "Heat Capacity of Organic Liquids," authored by W. M. Chow and John A. Bright, Jr. ("C.E.P.," April, 1953, page 175), discrepancies occur between some of the experimental values given in Table 3 and Table 6. For example, heat capacity at 20° C. of benzene is given as 0.340 in Table 3 and 0.407 in Table 6. The explanation is that values given in Table 3 are at or near 20° C., while those in Table 6 are at or interpolated to 20° C. Actually the value for benzene and toluene in Table 3 are at 10° C., the nearest found at that stage of the work.

These differences do not impair the usefulness of the correlation, since the correlations given in Table 3 and 6 are totally unrelated. However, errors might arise because of the temperature dependence of the constants given in Table 2.

An Investigation of Pressure Drop Through a Bubble Cap Plate

J. E. Cauley, Jr., Guy Z. Moore, and M. Van Winkle

University of Texas, Austin, Texas

One of the many variables to be considered in the design of bubble cap fractionating columns is pressure drop through the plate. This problem, one of a series in which the variables affecting the operation and design of bubble plate columns are being investigated, was undertaken to study experimentally, through a 2-ft. diam. plate, the effect of skirt clearance, weir height, vapor velocity, and liquid rate on pressure drop.

Data developed here are applicable only to a bubble cap plate similar to the one used in this investigation. Results reported were obtained in two separate studies, one in which pressure drop was determined as a function of weir height, and the other in which pressure drop was obtained as a function of skirt clearance.

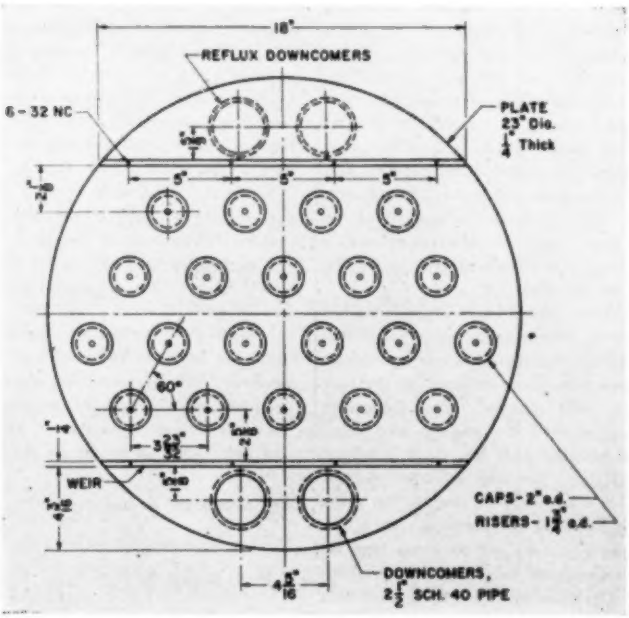


Fig. 1. Detail of plate.

Equipment

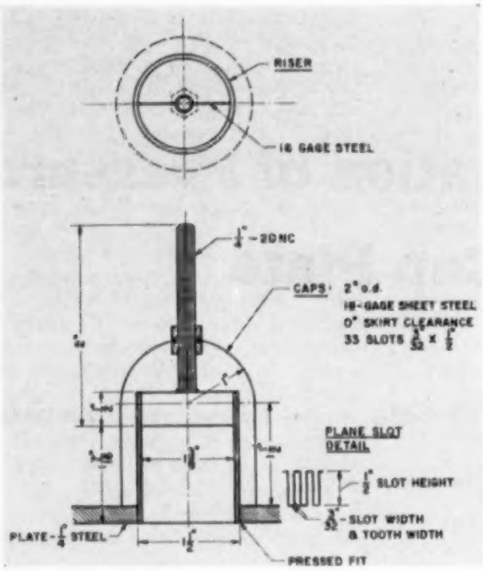
The column and plate used were the same for both phases of the study. The plate diameter was 23.0 in. with a thickness of 0.25 in. A detailed layout of the plate is shown in Figure 1. Twenty caps were used on the plate and were arranged in equilateral triangles spaced on 3 and 23/32-in. centers. The caps were of 2-in. O.D. and were made of 18-gauge sheet steel. Details of the cap and riser arrangements are shown in Figure 2.

Several weir sections made of 0.25-in. metal were provided in 0.5- and 1.0 in.-widths. The proper weir height was provided by screwing one of the weir sections on the plate, or one or more in combination. The ends of the weirs were caulked with a wax base modeling clay to prevent leakage and the edges were machined flat to prevent leakage through the weir sections when used in combination.

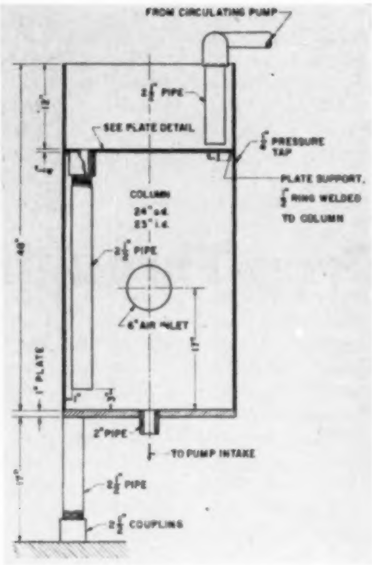
The column was made of a four-foot length of 24.0-in. O.D. pipe having a wall thickness of 0.25 in. An illustration of the major parts of the column and their dimensions appears in Figure 3. A ring of 0.5-in. round steel was welded to the column to provide support for the plate and the plate was clamped in the column by means of three J bolts. The joint between the plate and column was caulked with lead wool and painted with asphalt paint.

The bottom of the column was made of 1.0-in. steel plate and was arc-welded to the column. Three legs, fitted with couplings and short nipples, were welded to the bottom of the column to allow adjustment of the plate level. A 6-in. I.D. pipe was welded to the side of the column to provide an entry for the air. A 30-in. gauge

J. E. Cauley, Jr., is now associated with Humble Oil & Refining Co., Baytown, Tex., and G. Z. Moore with Celanese Corporation of America, Bishop, Tex.



◄ Fig. 2. Cross-section of assembled cap and riser.
Fig. 3. Detail of column. ►



glass was placed on the side of the column for measurement of the liquid level.

A centrifugal pump, rated at a maximum flow of 30 gal./min. and maximum head of 30 ft., was connected to the bottom of the column through a 2-in. pipe. The pump discharged through a 1.5-in. line which led to the reflux downcomers. An orifice union was placed in the line just before the downcomers. Orifices were available which covered a range of 0.527 through 18.5 gal./min./ft. of weir length. A 1.5-in. coupling was brazed to the union and was in turn brazed to the side of a 2.5-in. return bend which served as a header for the downcomers. Two sets of 2.5-in. pipe served as adjustable downcomers when the weir height was changed. Two 2.5-in. pipes were attached to the underside of the plate through couplings welded to the plate to serve as outlet downcomers. The outlet downcomers reached within 3 in. of the bottom of the column.

High pressure air (varying between 90 and 100 lb./sq.in. gauge) was furnished by compressors located about 500 ft. from the equipment. Two devices were provided for metering the air. For flow rates below 45 cu.ft./min. a Fischer and Porter bead guide rotameter with a 135-g. viscosity-immune float was used. The downstream pressure was indicated by a gauge calibrated from 0 to 100 lb./sq.in.

A 6.0-in. Venturi meter with a throat diameter of 2.0 in. was used for metering the air flow rates between 45 and 400 cu.ft./min. By means of two three-way cocks the differential pressure leads from the Venturi could be switched to either of two manometers. A 30-in. inclined manometer was furnished for differentials up to 5.0 in. of water. The angle of inclination provided 5 in. of scale for 1 in. of pressure differential. A standard 24-in. U tube manometer was used for pressure differentials between 5.0 and 24.0 in. Water was used as the fluid in all manometers. Six-inch galvanized stove pipe was used for the meter run to the Venturi and for carrying the air from the Venturi to the column. All joints and seams on the pipe were soldered.

The pressure drop through the plate could be read with an accuracy of 0.01 in. by means of a 10 to 1 inclined manometer.

Experimental Procedure

The orifices controlling the water flow rate were calibrated by measuring the weight of water through each orifice in a definite period of time. Both the rotameter and Venturi meter were calibrated to read in terms of air at 80° F. and 14.5 lb./sq.in. abs., the prevailing temperature and pressure.

The skirt clearance for the bubble caps was set by placing steel "set" blocks of the proper thickness beneath the caps and adjusting the two nuts on the riser bolt until the cap was level and at the proper clearance. The weir sections were screwed to the plate to give the desired weir height and the ends of the weirs were caulked with waxed base modeling clay. The column was filled with water until the water level was 6.0 in. above the bottom of the column. Four ounces of Mobil Hydratone, a chromate-type rust inhibitor, were added for each 10 gal. of water.

An orifice was placed in the orifice union and the circulating pump was started. The air flow was started and the rotameter reading and the downstream pressure as indicated by the pressure gauge were recorded. After the column reached equilibrium, the pressure drop across the plate was read from the 10 to 1 inclined manometer. Three flow rates were measured and the pressure drops recorded covering the range of flow measured by the rotameter.

The three-way cocks and the leads from the Venturi pressure taps were adjusted so that the differential pressure was read from the 5 to 1 inclined manometer. One intermediate air flow rate was measured and recorded. The pressure drop was read from the 10 to 1 inclined manometer and recorded.

The three-way cocks were then adjusted so that the differential pressure drop was read from the standard 24-in. U tube manometer. The air flow rate was increased, and three readings of air flow pressure drop and pressure drop across the plate were made and recorded, covering the range of the high air flow rates. In this manner, seven readings of the air flow measurement and pressure drop across the plate were made covering a range of flow rates of approximately 4 to 400 cu.ft./min.

The water and air to the column were closed off. The orifice controlling the liquid was removed, the next orifice was inserted, and the series of air flow-rate measurements and pressure-drop readings were repeated. After runs were made for each of the seven liquid rates, covering a range from 18.5 to 0.527 gal./min./ft. of weir length, the weir height was changed. The seven runs for each of the liquid rates were repeated for each of the weir heights, which ranged from 0.5 to 2.5 in. in 0.5-in. increments.

When runs were made covering each of the five weir heights, the column was shut down and the skirt clearance of the caps was changed. The skirt clearances were varied from 0.25 to 1.1875 in. in 0.25-in. increments, except for the last change from 1.0 to 1.1875 in.

In addition to these runs, the pressure drop across the dry plate was determined at all skirt clearance, including zero skirt clearance. The procedure was the same as just described with the exception that there was no liquid flowing and weir height had no effect.

Comments on Experimental Results

Effect of Variables on Pressure Drop

SKIRT CLEARANCE

All other variables being held constant, as the skirt clearance was in-

creased, the pressure drop decreased, as shown in Table 1. The reason for the decrease was that as the skirt clearance increased, with constant mass velocity, constant liquid rate, and a constant weir height, the liquid head above the slots was decreased proportionately.

WEIR HEIGHT

As the weir height was increased, the pressure drop was increased. At constant air mass velocity, constant liquid rate, and constant skirt clearance, the liquid head above the slots was increased with the increase in weir height. Table 2 illustrates the change in pressure drop with the change in weir height.

LIQUID RATE

The pressure drop was increased with an increase in liquid rate. Table 3 illustrates the effect of liquid rate on pressure drop when the air mass velocity, skirt clearance, and weir height were held constant. As the liquid rate was increased, the liquid head above the weir increased thus increasing the pressure drop. This indicates that the weir height is not a true indication of liquid head on the plate.

MASS VELOCITY

Above an air mass velocity of approximately 60 lb./(hr.)(sq.ft.), the pressure drop was increased with an increase in the mass velocity. Below a mass velocity of 60 lb./(hr.)(sq.ft.), there is a definite dip in the pressure-drop curve, as shown in Figures 10, 11, and 12 and Table 4. The drop grew more pronounced as the weir height increased for a constant skirt clearance. It is believed that the decrease in pressure drop indicated the region in which *weeping* was taking place and the plate was unstable. Weeping is used to define this region rather than *dumping*, since through observation during the experimental runs, all of the individual caps were seen to be operating intermittently. As the pressure built up beneath the caps, several bubbles would be released from one or two caps at a time depending probably on the variations in liquid head above the individual caps because of turbulence in the liquid flowing and agitation caused by bubbles previously released by other caps. As long as the air velocity remained constant at low rates, the above cycle was continuously repeated with all of the caps bubbling intermittently. During the time the individual caps were not operating, liquid flowed down through the cap risers. In all cases when the air velocity reached approximately 60 lb./(hr.)(sq.ft.), all caps were operating continuously and the pressure drop was starting to increase with an increase in air velocity.

The high pressure drop initially at the minimum air velocity and the subsequent decrease in pressure drop can possibly be attributed to at least two factors: at low air velocities part of the caps were not bubbling and liquid was flowing down the risers, thus, only part of the risers was taking the total air flow. The velocity of the air was therefore increased, and because of the orifice effect, larger pressure drops were experienced than would be attained from the same amount of air flow through the larger riser area when all caps were operating. Also, the actual liquid head was probably at a maximum while bubbling was at a minimum. As bubbling increased, aeration increased, and, because the overflow weir height remained fixed, actually less of the liquid than that represented by the nonaerated liquid held on the plate by the weir was kept on the plate. The more pronounced dips and longer recovery periods at the higher weir heights were caused by the increased liquid head above the slots. At low weir heights the dip was slight, depending, of course, on the height of the slots in relation to the top of the weir.

Residual Pressure Drop

An interesting correlation for the pressure drop through a perforated plate was obtained by Arnold, Plank, and Schoenborn (*1*) by plotting the pressure drop vs. air mass velocity at parameters of both weir height and liquid rate on log-log paper. The major portions of the curves were straight lines having positive slopes and tending to converge to a focal point lying to the right and off the graph. These slopes were found to increase as the liquid rate and the weir height were increased. At low air velocities each of the curves

Table 1.—Effect of Skirt Clearance on Pressure Drop

Air Mass Velocity = 300 lb./(hr.)(sq.ft.)
Liquid Rate = 12.9 gal./min./ft. of weir length

WEIR HEIGHT = 1.5 IN.		WEIR HEIGHT = 2.5 IN.	
Skirt Clearance in.	Pressure Drop inches of water	Skirt Clearance in.	Pressure Drop inches of water
0.00	1.81	0.00	2.38
0.25	1.66	0.25	2.16
0.50	1.49	0.50	2.01
0.75	1.36	0.75	1.93
1.00	1.20	1.00	1.82
		1.1875	1.76

Table 2.—Effect of Weir Height on Pressure Drop

Air Mass Velocity = 300 lb./(hr.)(sq.ft.)
Liquid Rate = 12.9 gal./min./ft. of weir length

SKIRT CLEARANCE = 0.25 IN.		SKIRT CLEARANCE = 0.75 IN.	
Weir Height in.	Pressure Drop inches of water	Weir Height in.	Pressure Drop inches of water
1.0	1.33	1.5	1.36
1.5	1.66	2.0	1.67
2.0	1.94	2.5	1.93
2.5	2.16		

Table 3.—Effect of Liquid Rate on Pressure Drop

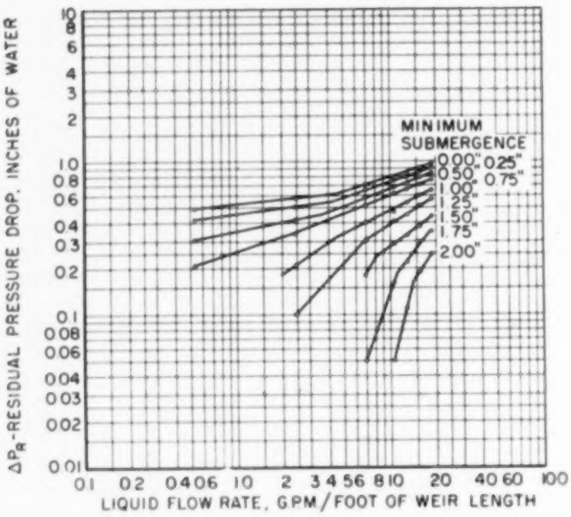
Air Mass Velocity = 300 lb./(hr.)(sq.ft.)
Skirt Clearance = 0.50 in.

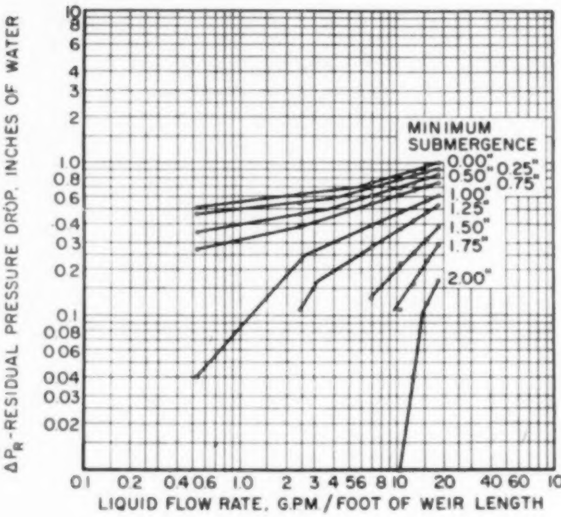
WEIR HEIGHT = 1.5 IN.		WEIR HEIGHT = 2.5 IN.	
Liquid Rate gal./min./ft. of weir length	Pressure Drop inches of water	Liquid Rate gal./min./ft. of weir length	Pressure Drop inches of water
0.527	1.11	0.527	1.53
2.41	1.22	2.41	1.66
6.87	1.38	6.87	1.86
10.5	1.45	10.5	1.97
12.9	1.49	12.9	2.01
15.6	1.55	15.6	2.08
18.5	1.59	18.5	2.14

Table 4.—Effect of Air Mass Velocity on Pressure Drop

Liquid Rate = 10.5 gal./min./ft. of weir length
Skirt Clearance = 1.00 in.

WEIR HEIGHT = 1.5 IN.		WEIR HEIGHT = 2.5 IN.	
Air Mass Velocity lb./(hr.)(sq.ft.)	Pressure Drop inches of water	Air Mass Velocity lb./(hr.)(sq.ft.)	Pressure Drop inches of water
5	0.67	5	1.53
15	0.61	15	1.43
25	0.58	25	1.40
50	0.64	50	1.48
100	0.75	100	1.49
200	0.94	200	1.66
300	1.16	300	1.76
400	1.36	400	1.88
500	1.54	500	1.98
600	1.76	600	2.12



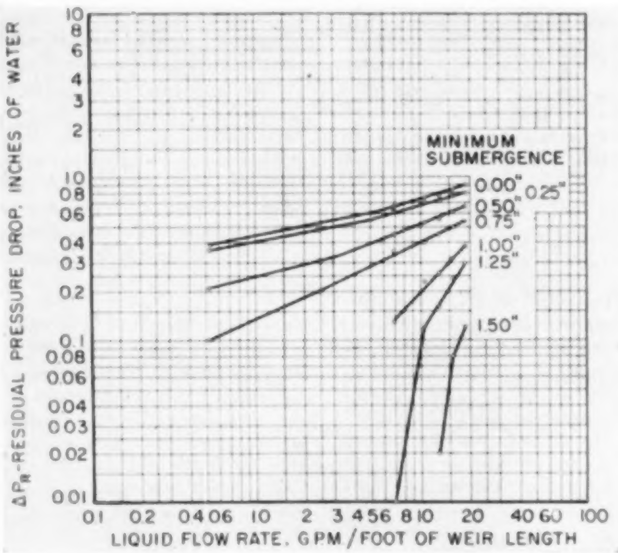


had a portion which approached a horizontal straight line, but having a slight positive slope. This *horizontal* portion of the curve was attributed to the instability of the plate at the low air velocities. The authors reported that water drained freely through the holes adjacent to the inlet weir at the low velocities and little bubbling took place. As the air velocity was increased, some perforations became operative, the number increasing steadily until all holes were bubbling at the point where the two portions of the curve intersected. Above that point the plate operation was stable.

Fig. 4. Left, residual pressure drop vs. liquid flow rate. Air mass velocity = 193 lb./(hr.)(sq.ft.).

Fig. 5. Right, Residual pressure drop vs. liquid flow rate. Air mass velocity = 290 lb./(hr.)(sq.ft.).

Fig. 6. Below, Residual pressure drop vs. liquid flow rate. Air mass velocity = 483 lb./(hr.)(sq.ft.).



For the sake of comparison with the work of Arnold, Plank, and Schoenborn, the experimental pressure drop through the bubble cap plate was plotted on log-log paper vs. air mass velocity at constant liquid rate and parameters of constant minimum submergence (weir height minus the distance from the plate surface to the top of the slots). Although the lower portion of the curve was reproduced as a straight line having a slight slope, the upper portion was found to have a slight positive curvature.

By subtracting the pressure drop through the dry plate and the minimum submergence from the total pressure drop through the plate, a more satisfactory means of comparison was obtained. The remaining pressure drop was arbitrarily defined as the residual pressure drop. The residual pressure drop was plotted on log-log paper vs. liquid rate at constant air mass velocities and parameters of constant minimum submergence. These curves are shown in Figures 4, 5, and 6. Circles indicating data points were the average of the data points at that liquid rate and air mass velocity.

The portion of the curves above a liquid rate of approximately 3 gal./min./ft. of weir length was a straight line with a positive slope. The slopes increased with an increase in minimum submergence. For a constant minimum submergence the slope was approximately the same regardless of the air velocity, although the intercept for each of the curves changed with a change in air velocity.

Straight lines with positive slopes which increased sharply as the minimum submergence increased made up the lower portion of the curves. At a minimum submergence of 1.00 in. the slopes of the lower portion of the curves started to exceed the slopes of the upper portions. The lower portions of the curves coincided with observations of a tendency, made during the experimental runs, for much of the liquid transfer over the outlet weir to be in the form of splashing at the lower liquid rates. A plot drawn from the data of Arnold, *et al.*, also resulted in straight lines when the total pressure drop was plotted on log-log paper vs. liquid rate at constant air velocity. However, the results were inconclusive since runs were made at only three to four liquid rates.

A more extensive investigation should be made before any definite conclusions can be drawn. The plots seem to indicate that the pressure drop might be predicted by means of focal point and slopes.

Correlation

PREVIOUS WORK

In recent years many articles have appeared in the literature on the subject of pressure drop through bubble cap plates. Much data and many equations presented have been calculated on a theoretical basis and no comprehensive quantities of experimental data have appeared. A survey article by Ju Chin Chu (*2*) was published in 1951 in which some recent articles were reviewed.

Pressure-drop studies on 3-in. and 4-in. bubble caps were presented in an article by Kemp and Pyle (*5*). However, the applicability of their data for design work is questioned, since long and rather narrow plate sections were used for the tests. The effect of liquid flow on this type of plate could hardly be compared with the effect of liquid flow on a circular plate.

A study of the aeration effect of the liquid on the pressure drop was also discussed. Aeration of the deep liquid seals at the inlet weir was found to increase the vapor velocity required for stability, while at the outlet weir the pressure drop in the adjacent caps was increased by poor distribution of the vapor and the vapor velocity required for stability was lowered. These two effects were said to be counterbalanced by each other, and the depth of liquid above the cap slots was said to be uniform across the plate.

A correlation for the pressure drop through the dry bubble cap as a function of the air velocity through the slots was presented by Eld (*4*). The pressure drop was given by the following equation:

$$h_v = K_v \frac{V_1^2}{2g} D_v \qquad (1)$$

where

h_v = pressure drop caused by vapors flowing through dry bubble caps, mm. Hg,
V_1 = vapor velocity in riser, ft./sec.,
D_v = density of vapors, lb./cu.ft.,
K_v = constant (a function of the cap design).

Equations for calculating the pressure drop across bubble trays were presented by Cicalese, *et al.*, (*3*). The equations were presumably derived from design data used by several companies and were in the main exponential equations based on the liquid and vapor densities and the geometry of the plate. Equations and charts were also presented for the correction of the pressure drop through the dry caps caused by liquid on the plate and for the pressure drop caused by the liquid head over the weir.

The pressure drop across a bubble cap plate was separated into component parts by Rogers and Thiele (*7*). The three-component parts were defined as pressure drop through the cap riser and annular space, pressure drop through the slots, and pressure drop through the head of liquid on the plate. Theoretical equations were developed for the pressure drop through the riser, annular space, and slots. The pressure drop through a single rectangular slot for an air-water system was presented as follows:

$$V_s = (0.51)(0.078)h^{7/4} \qquad (2)$$

where

V_s = volume flow through one slot, cubic feet per second,
h = head of liquid, inches,
$V = NV_s$ = volume per cap, and
N = number of slots per cap.

In actual practice, the slot opening would be affected by changes in liquid head and vapor velocity, limiting the use of the equation.

Method of Correlation

The best approach to a method of correlation appeared to be that of separating the total pressure drop through the plate into its component parts. The total pressure drop was finally considered to be composed of the pressure drop through the dry plate, the pressure drop caused by the minimum liquid seal or minimum submergence, and a residual pressure drop.

The pressure drop through the dry plate was measured at the various skirt clearances during the experimental runs. This pressure drop was plotted vs. air mass velocity at parameters of constant skirt clearance. These curves were found to fit equations of the type described by Eld (4), the pressure drop being a function of the velocity squared. It was interesting to note that for a constant air mass velocity, the pressure drop across the dry plate was not found to decrease with an increase in skirt clearance. For a constant mass velocity the pressure drop was found to be at a maximum for a zero skirt clearance and to decrease to a minimum at a skirt clearance of 0.50 in. The pressure drop was then found to rise to another maximum at a skirt clearance of 1.00 in. and then to decrease for the limiting skirt clearance of 1.1875 in.

A skirt clearance of 1.1875 in. was considered to be the limiting skirt clearance because at this height the tops of the slots were level with the tops of the cap risers.

The maximum to minimum increase in the pressure drop through the dry plate as the skirt clearance increased at constant air velocity was believed to be caused by the changes in expansion and contraction losses, and change of direction losses within the caps. Values of the pressure drop through the dry plate were checked against the values calculated by means of the equations of Cicalese, *et al.* (3). Consistent correlation could not be obtained. The difference in the experimental and calculated values was attributed to the difference in the size and design of the caps. Further data on different caps and arrangements are necessary to enable definite conclusions to be made.

The minimum submergence was arbitrarily defined as the weir height minus the distance from the plate surface to the top of the slots in inches of clear water to facilitate its use as a design factor and to eliminate the necessity of determining the height of the liquid over the outlet weir, the liquid gradient, or the average height of the liquid over the weir. Skirt clearance, weir height, slot height, and minimum submergence for this correlation are illustrated in Figure 7.

The residual pressure drop was defined as the remaining pressure drop after subtracting both the pressure drop through the dry plate and the minimum submergence. The residual pressure drops were found to become increasingly negative at minimum submergences above 1.50 in. and air velocities above 400 lb./(hr.)(sq.ft.) for a constant liquid rate of 18.5 gal./min./ft. of weir length. These curves are presented in Figure 8, based on a liquid rate of 18.5 gal./min./ft. of weir length.

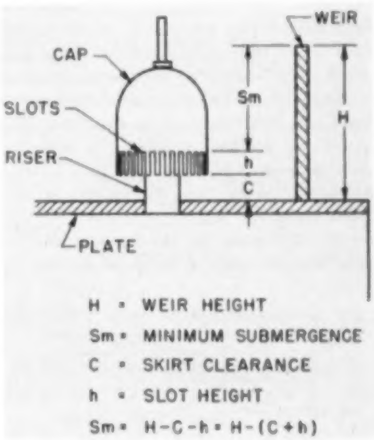


Fig. 7. Schematic nomenclature diagram.

The maximum deviation for the values of the residual pressure drop from the total pressure drop at the same mass velocity, liquid rate, and minimum submergence was approximately 0.40 in. of water down to a liquid rate of 0.527 gal./min./ft. of weir length. To determine the points for plotting the residual pressure-drop curves for a constant liquid rate, the values of the residual pressure drop at the same air mass velocity and same minimum submergence were averaged. This process was repeated for each of the experimental data points for all of the liquid rates.

As the liquid rate was decreased, the residual pressure drops were found to decrease further and to become negative at progressively lower air velocities and minimum submergences. The decreasing and negative residual pressure drops were believed to be caused by aeration of the liquid, by a natural decrease in liquid head above the slots with decreasing liquid rates, and by the splashing of liquid over the weir at high air velocities.

At liquid rates of 2.41 gal./min./ft. of weir length, and below, the tendency at high air velocities was for most of the liquid flowing to be transferred over the weir by splashing rather than by direct flow over the weir. The average liquid level was below the top of the weir under these conditions.

In order to present a method of correlation which was convenient and easy to use, as well as retaining sufficient accuracy for the possible prediction of design data, the residual pressure-drop plot for 18.5 gal./min./ft. of weir length was made the basis for the correlation and no other residual pressure-drop plots are presented. Curves for the pressure drop as functions of the air mass velocity are both shown in Figure 8.

To predict pressure drops for liquid rates other than 18.5 gal./min./ft. of weir length, a correction factor was found necessary. For each of the averaged data points for each constant liquid rate, the residual pressure drop, calculated previously, was subtracted from the corresponding residual pressure drop at 18.5 gal./min./ft. of weir length.

The difference in residual pressure drops was found to be a constant within a maximum deviation of 0.02 in. of water for each liquid rate down through 10.5 gal./min./ft. of weir length. Below liquid rates of 10.5 gal./min./ft. of weir length the difference was found to be a function of the minimum submergence in addition to the liquid rate. The differences were constant within a maximum deviation of 0.05 in. of water for each minimum submergence at each constant liquid rate below 10.5 gal./min./ft. of weir length down to 0.527 gal./min./ft. of weir length. Differences for the latter liquid rate were constant within a maximum deviation of 0.12 in. of water. This high deviation at the lowest liquid rate was to be expected since little liquid was flowing at this rate.

In Figure 9 the correction factor in inches of water is shown plotted vs. liquid rate in gallons per minute per foot of weir length at parameters of constant minimum submergence.

Proposed Correlation

The total pressure drop through the bubble cap plate can be predicted by the following equation:

$$\Delta P = \Delta P_c + S_m + \Delta P_r - \Delta_l \quad (3)$$

where

ΔP = total pressure drop through plate, inches of water;

ΔP_c = pressure drop through dry plate, inches of water;

S_m = minimum submergence, inches of water;

ΔP_r = residual pressure drop, inches of water; and

Δ_l = correction factor for liquid rate, inches of water.

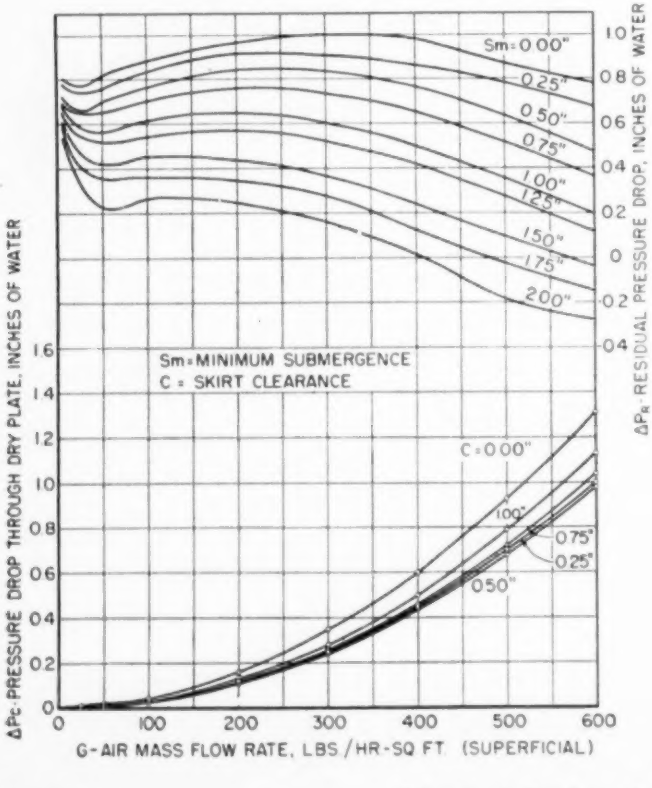
Knowing the air mass velocity, liquid rate, skirt clearance, slot height of the caps, and weir height of the proposed plate, all the component parts of the total pressure drop can be determined directly. The pressure drop through the dry plate, ΔP_c, is determined from Figure 8. The minimum submergence, S_m, is determined by subtracting the skirt clearance plus the height of the slots from the weir height (Figure 7 for schematic definitions). The residual pressure drop, ΔP_r, is determined from Figure 8. The correction factor for liquid rate, Δ_l, is determined from Figure 9.

No attempt was made to develop a rigorous mathematical expression for this correlation since the interrelation of the variables was obviously too complex to obtain a sufficient degree of accuracy.

Comparison of Experimental and Calculated Data

Plots of eleven runs showing both the experimental and calculated data plotted on the same scale are presented in Figures 10-12. The experimental pressure drops for a random selection of data points are presented in Table 5 with the pressure drop calculated from the correlation, the deviation from the experimental, and the per cent error. For each liquid rate the maximum deviation and per cent error, and the average deviation and per cent error are presented. At the end of Table 5 the over-all deviations and per cent errors are noted.

Both the deviations and per cent errors increase as the liquid rate decreases. However, liquid rates below 2 to 3 gal./min./ft. of weir length are seldom encountered. In all cases the maximum deviation reported for the liquid rate was an isolated point and was usually found in the range of operation where the plate was unstable; *i.e.*, the region where the pressure-drop curves showed a dip. The average deviation for each liquid rate was equal to or within the range of experimental error, and for liquid rates above 6.87 gal./min./ft. of weir length the maximum deviation



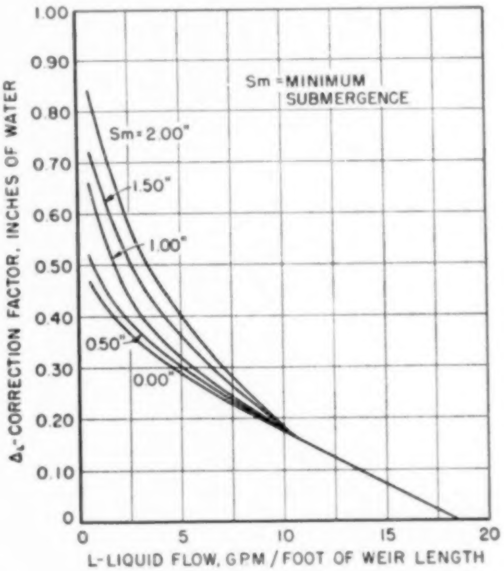


Fig. 9. Correction factor vs. liquid flow. ▲

◄ Fig. 8. Pressure drop through dry plate and residual pressure drop vs. air mass flow rate.

Table 5.—Comparison of Experimental and Calculated Data

Liquid Rate = 18.5 gal./min./ft. of weir length
Skirt Clearance = 0.5 in.

MASS VELOCITY LB./(HR.)(SQ.FT.)	S_m	ΔP CALC.	ΔP EXP.	DEVIATION INCHES OF WATER	PER CENT ERROR
25	0.0	0.77	0.77	0.00	0.00
100	0.5	1.30	1.32	−0.02	−1.52
300	1.0	1.84	1.86	−0.02	−1.08
500	1.5	2.28	2.26	0.02	0.88

Maximum Deviation = 0.05 inches of water
Average Deviation = 0.02 inches of water
Maximum Per Cent Error = 6.1%
Average Per Cent Error = 1.3%

Liquid Rate = 12.9 gal./min./ft. of weir length
Skirt Clearance = 1.0 in.

MASS VELOCITY LB./(HR.)(SQ.FT.)	S_m	ΔP CALC.	ΔP EXP.	DEVIATION INCHES OF WATER	PER CENT ERROR
25	0.0	0.65	0.62	0.03	4.84
100	0.5	1.18	1.17	0.01	0.85
300	0.5	1.50	1.55	−0.05	−3.23
500	1.0	2.02	2.02	0.00	0.00

Maximum Deviation = 0.06 inches of water
Average Deviation = 0.02 inches of water
Maximum Per Cent Error = 4.9%
Average Per Cent Error = 1.6%

Liquid Rate = 6.87 gal./min./ft. of weir length
Skirt Clearance = 0.25 in.

MASS VELOCITY LB./(HR.)(SQ.FT.)	S_m	ΔP CALC.	ΔP EXP.	DEVIATION INCHES OF WATER	PER CENT ERROR
25	0.25	0.75	0.72	0.03	4.17
100	0.75	1.23	1.23	0.00	0.00
300	1.25	1.75	1.80	−0.05	−2.78
500	1.75	2.21	2.13	−0.01	−0.47

Maximum Deviation = 0.09 inches of water
Average Deviation = 0.03 inches of water
Maximum Per Cent Error = 7.8%
Average Per Cent Error = 2.3%

Liquid Rate = 0.527 gal./min./ft. of weir length
Skirt Clearance = 0.0 in.

MASS VELOCITY LB./(HR.)(SQ.FT.)	S_m	ΔP CALC.	ΔP EXP.	DEVIATION INCHES OF WATER	PER CENT ERROR
15.4	0.0	0.32	0.30	0.02	6.67
96.5	0.5	0.78	0.71	0.07	9.86
289.5	1.0	1.28	1.30	−0.02	−1.54
482.5	1.5	1.77	1.73	0.04	2.31

Maximum Deviation = 0.14 inches of water
Average Deviation = 0.05 inches of water
Maximum Per Cent Error = 19.6%
Average Per Cent Error = 5.8%

Overall Maximum Deviation = 0.16 inches of water
Overall Average Deviation = 0.03 inches of water
Overall Maximum Per Cent Error = 19.6%
Overall Average Per Cent Error = 2.7%

was also within the range of experimental error.

By limiting the range of applicability of the correlation to the range of air mass velocities in the stable region of operation and practical liquid rates, both the deviations and per cent errors would be reduced considerably.

Acknowledgment

The authors wish to express appreciation to Dr. B. J. Lerner, chemical engineering department, University of Texas, for his valuable suggestions in correlating the data. It is also desired to express appreciation to the Pressed Steel Corp., Wilkes-Barre, Pa., for providing the bubble caps used in this study, and to the Tennessee Gas Transmission Co., Houston, Tex., for providing the casing used for the column shell.

Notation

ΔP = total differential pressure through plate, in. of water

ΔP_c = pressure drop through dry plate, in. of water

S_m = minimum submergence, weir height minus distance from plate surface to top of slots, in.

ΔP_r = residual pressure drop, total pressure drop minus pressure drop through dry plate and minus minimum submergence, in. of water

Δ_L = correction factor for liquid rate, in. of water

Literature Cited

1. Arnold, D. S., C. A. Plank, and E. M. Schoenborn, *Chem. Eng. Progress*, **48**, No. 12, 633 (1952).
2. Chu, Ju Chin, *Petroleum Engr.*, **23**, No. 3, C9-16 (1951).
3. Cicalese, J. J., *et. al.*, *Petroleum Refiner*, **26**, No. 4, 141 (1947).
4. Eld, Aksel C., *Petroleum Refiner*, **27**, No. 10 119 (1948).
5. Kemp, H. S., and C. Pyle, *Chem. Eng. Progress*, **45**, 435 (1949).
6. Moore, Guy Z., Thesis, The University of Texas, Austin (1951).
7. Rogers, M. C., and E. W. Thiele, *Oil Gas J.*, **33**, No. 5, 52 (1934).

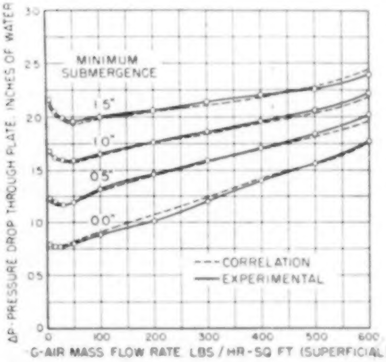


Fig. 10. Pressure drop vs. air mass flow rate. Liquid flow = 18.5 gal./min./ft. of weir length. Skirt clearance = 0.5 in.

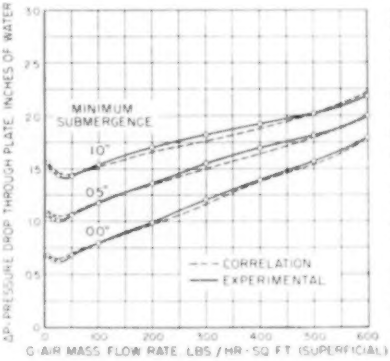


Fig. 11. Pressure drop vs. air mass flow rate. Liquid flow = 12.9 gal./min./ft. of weir length. Skirt clearance = 1.0 in.

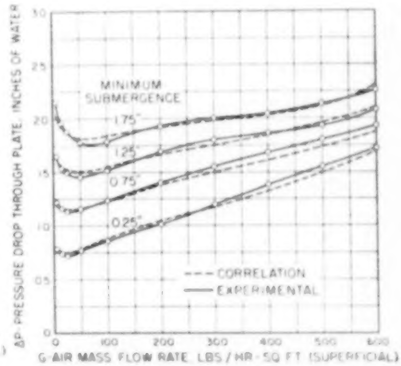


Fig. 12. Pressure drop vs. air mass flow rate. Liquid flow = 6.87 gal./min./ft. of weir length. Skirt clearance = 0.25 in.

ABSTRACTS

*Abstracts of papers published in "Phase-Equilibria—Collected Research Papers for 1953," Chemical Engineering Progress Symposium Series No. 6, Vol. 49 (1953). The volume may be purchased from Chemical Engineering Progress, 120 East 41 Street, New York 17, New York.**

Nitrogen-Methane Vapor-Liquid Equilibria

M. R. Cines, J. T. Roach, R. J. Hogan, and C. H. Roland
Phillips Petroleum Company

Low-temperature vapor-liquid equilibria of nitrogen-methane mixtures were determined at —280°, —260°, —240°, —232.8°, —220°, —180°, and —150° F. The experimental data were smoothed and correlated by means of an empirical relation, $\log P = A/T + B$, for constant-vapor and -liquid composition, where P is pressure in lb./sq.in. abs. and T is the temperature in degrees Rankine. Comparison with the data of Torochesnikov and Levius at —280° F. indicates that their data are in error.

Chem. Eng. Progress Symposium Series, **49**, No. 6, 1 (1953).

Liquid-Vapor Phase Behavior of the Methane-Nitrogen System

O. T. Bloomer and J. D. Parent
Institute of Gas Technology

Liquid-vapor phase-equilibrium data for the methane-nitrogen system have been determined by a study of pressure-volume-temperature relationships of the pure components and nine binary mixtures thereof. The range covered is from atmospheric pressure through the critical region. P-T, T-X, and P-X diagrams and charts relating the vaporization-equilibrium constant to pressure and temperature have been prepared, and diagrams have been constructed to show the effect of composition on critical pressure and temperature.

Chem. Eng. Progress Symposium Series, **49**, No. 6, 11 (1953).

Correlation of Nitrogen-Methane Vapor-Liquid Equilibria by Equation of State

H. H. Stotler and Manson Benedict
Hydrocarbon Research, Inc.

The Benedict-Webb-Rubin equation of state has been evaluated for pure nitrogen from existing data on P-V-T properties, vapor pressure and the critical point, Joule-Thomson coefficients, second virial coefficients, and isothermal changes of enthalpy. An equation of state of the Benedict-Webb-Rubin form, from which a simplified correlation has been prepared, has been successfully fitted to the vapor-liquid equilibrium data of Cines et al. [*see* above] for the system nitrogen-methane.

Chem. Eng. Progress Symposium Series, **49**, No. 6, 25 (1953).

Ethane-Ethylene System Vapor-Liquid Equilibria at 0°, —40°, and —100° F.

G. H. Hanson, R. J. Hogan, F. N. Ruehlen, and M. R. Cines
Phillips Petroleum Company

The data for each isotherm concerned were smoothed by means of activity coefficients based on fugacities and five-suffix equations obtained from generalized expressions reported by Benedict, Johnson, Solomon, and Rubin. The values of the constants for these activity-coefficient equations were selected so that the net area under the curve of the logarithm of the ratio of the activity coefficients as a function of liquid composition was equal to zero. The resulting activity coefficients obey the Gibbs-Duhem and the Scatchard excess-free-energy relationships and yield smooth p-x-y curves that are in good agreement with the experimental data.

Chem. Eng. Progress Symposium Series, **49**, No. 6, 37 (1953).

Equilibrium Vaporization of Reduced Crudes at Subatmospheric Pressures

T. H. Paulsen
Sinclair Research Laboratories, Inc.

A correlation based on experimental data is presented for predicting the subatmospheric equilibrium-flash-vaporization characteristics of reduced crudes. In the absence of experimental flash data, an empirical relationship between 5-mm.-Hg-abs. Engler-type distillation and the 5-mm.-Hg equilibrium-flash curve is presented.

Chem. Eng. Progress Symposium Series, **49**, No. 6, 45 (1953).

Effect of Pressure on Vapor-Liquid Equilibria for the System Ethyl Alcohol—Water

Henry Otsuki and F. Campbell Williams
University of California, Berkeley

A modified Gillespie still used in the experimental determination of the vapor-liquid-equilibrium relationship is described. Isobaric-vapor-liquid-equilibrium data were determined for the system at 1 atm., 50, 100, 200, and 300 lb./sq. in. abs. Thermodynamic consistency of the experimental data is shown by plots of the logarithm of the ratio of the activity coefficients vs. the liquid mole fraction. The van Laar equation is shown to be applicable for the system over the experimental pressure range, and the variation of the van Laar constants A and B with pressure is indicated.

Chem. Eng. Progress Symposium Series, **49**, No. 6, 55 (1953).

Applications of Integral Distillation Calculation Method

Wayne C. Edmister and Donald H. Buchanan
Carnegie Institute of Technology

Two applications of the recently proposed integral method of making equilibrium-flash-vaporization calculations for petroleum fractions are presented. One of these applications is to irregularly shaped true-boiling-point curves by a segmental procedure. The other is to the solution of multistage-fractional-distillation calculations for petroleum fractions.

Chem. Eng. Progress Symposium Series, **49**, No. 6, 69 (1953).

Prediction of Critical Temperatures and Critical Pressures of Complex Hydrocarbon Mixtures

Elliott I. Organick
United Gas Corporation

A simple correlation is proposed for predicting the critical pressures and temperatures of complex hydrocarbon mixtures. These critical properties are related directly to the composition of the mixture with the aid of two generalized composition parameters: a molal-average and a weight-average property.

The critical pressure and temperature for any complex mixture may be located simultaneously on a single plot from a point located on a grid formed by discrete values of the two composition parameters. The value for each parameter

(Continued on page 565)

* See advertisement on page 74.

Sluicing Pressure Leaf Filters

Edward A. Ulrich Buffalo, New York

For many semicontinuous or batch-type pressure filtrations, the sluicing pressure leaf filter produces high-clarity filtrates (½ to 1 p.p.m. solids) and offers cleanliness, totally enclosed operation, low maintenance and operating cost, and reduced labor. It also eliminates manual cake handling. To apply sluicing filters properly, the filtration engineer must consider characteristics of cake solids, allowable maximum amounts of sluice liquor, use of filter aids, disposal and/or recycling of cake slurries, and type of sluice or spray nozzles to be utilized.

A sluicing pressure leaf filter may be described as a filter body designed for pressure operation applied by external force of as much as 100 lb./sq.in. and in some special cases higher, which contains vertical leaves providing a solids retention medium to effect separation on both sides. The sluicing discharge of the solids from the leaf media is accomplished by manually directed liquor (or water) or by mechanically operated spraying devices when the tank has been emptied of prefilt liquid after further cake building is no longer equal to process requirements. This paper deals with mechanical sluicing devices and filter designs for sluicing discharge.

History

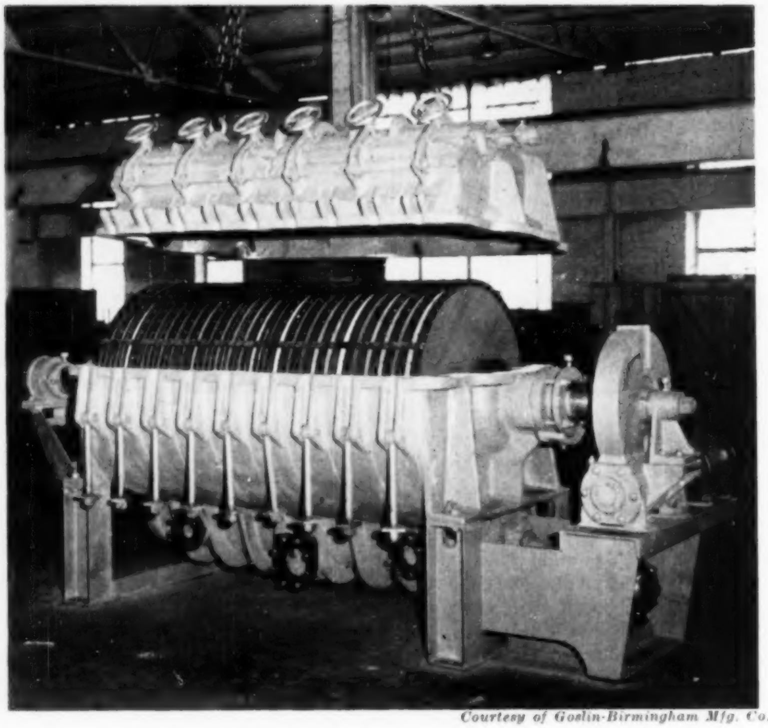
Near the turn of the century, the first successfully applied sluicing filter was introduced to gold cyanide processes by C. W. Merrill (*1*). The Merrill filter was a modified plate and frame with a sluicing header extending through the central eye and grommets sealing the cloth at this point like a recessed plate press. Sprays rotated with the externally driven header to erode cakes from the cloth medium and discharged the slurry from a corner eye. This development was followed by Sweetland's sluicing pressure leaf filter, the first of its kind. Vallez (*see* Fig. 1) joined the market a little later with a good sluicing design, although it contained drawbacks of mechanical complication and leaf inaccessibility. It is still highly efficient by modern standards. Still later the Suchar Auto filter was especially designed for the sugar-refining industry. This filter improved on the Vallez design by providing individual atmospheric outlets for each leaf, and leaves that could be individually removed when the filter was open. The first pair of auto filters was installed at the present Southdown Refinery, Houma, La., in 1928 (*2*). Hercules and Niagara have marketed industrial-size sluicing filters in the past ten years. Hercules employs woven-wire filter media and the Vallez sluicing principle, substituting a quick-opening end closure for the split case. The first Niagara Auto-Sluice filter was installed in Michigan Sugar Company's Crosswell factory in 1946 on thick juice standard liquor and sluiced with thin juice (*3*). A typical Auto-Sluice filter is shown in Figure 2.

Meanwhile rotary vacuum drum filter applications have continued at a rapid pace and have provided practically continuous operation. However, sluicing filters are still desirable in those fields where cake will not discharge freely from the medium in the usual manner of porous cakes on a semidry basis. Such cakes are generally referred to as nonhomogeneous sludges of low porosity.

Edward A. Ulrich, who received a B.S. degree in chemical engineering from Purdue University, is well acquainted with filtration. The article printed here comes from a symposium presented at the Cleveland meeting of the A.I.Ch.E.; at the time Mr. Ulrich was with the Niagara Filter Corp., Buffalo, N. Y., prior to its sale to American Machine and Metals, Inc. Mr. Ulrich has written several articles on filtration and is executive vice-president and general manager of Process Filters, Inc., also of Buffalo.

These are most difficult to discharge because of their cohesion, tenacity, and slimy or gelatinous nature. Pressure filtration is useful in the separation of these cakes and, when properly engineered, produces a good sluicing application.

Most engineers dealing with chemical processes favor automatic or continuously operated equipment. Sluicing filters have already made progress in this direction. Unlike the continuous operation of rotary vacuum filters, automatic operation of sluicing filters is intermittent. It retains all the normal functions but is controlled by time-cycle instrumentation (*4*). Isolated modified examples of this operation are in Corn Products Refining Company's Corpus Christi, Tex., and Pekin, Ill., plants, using Sweetlands and Niagaras respectively to produce glucose by automatic controls.



Courtesy of Goslin-Birmingham Mfg. Co.

Fig. 1. Vallez filter with cover raised. Sluice header is shown as pipe extension to right of upper body.

Characteristics

In many respects, the sluicing filter is an ideal filter, but the basic requirements of application must be carefully considered. These characteristics emerge:

No manual cake handling.
Clean filter-station housekeeping.
Reduced filtration cost per pound of product.
Elimination of labor "bull-work."
Moderate maintenance.
Elimination of frequent cloth washing and/or replacement.
Totally enclosed operation for hazardous products.
Potential automatic operation.

Diatomaceous-earth filter aids or other products of similar purpose are most important in the application of sluicing filters for the precoat protection they give to the medium; they hinder blinding of the medium and promote sluicing discharge. These filter-aid precoats on wire-cloth media are most satisfactory and successfully eliminate fabric cloths at appreciable savings. When added to the prefilt liquors of difficult filtering solids, filter aids permit a control of the porosity which may be exercised within limits. Such cakes are found in the sugar industry. The food industry also provides similar cakes in weak pectin liquors, gelatins, beer and beer worts, fruit-juice pulps, recovery of scrap candy, and the like. Filtering of antibiotic broths is considered a standard application for sluicing filters in the fermentation industry. A variety of cakes that respond to pressure filtration and sluicing is found in the chemical field. Also, hazards to operators and plant property may be eliminated by the totally enclosed operation of sluicing filters, and consequently they may be more broadly applied.

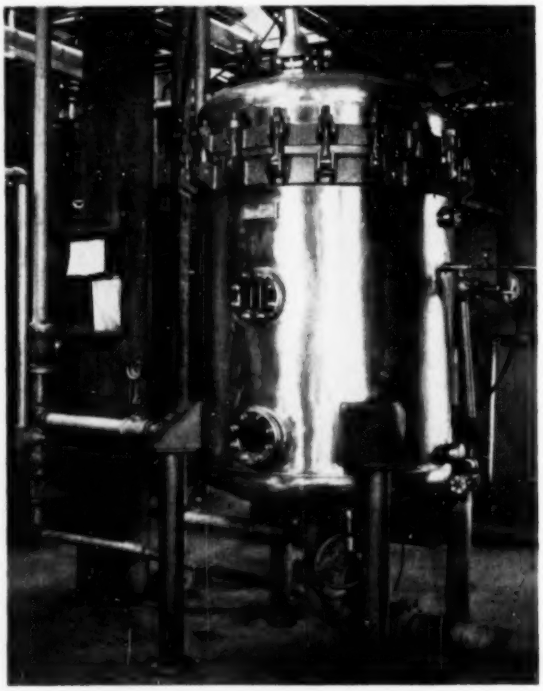


Fig. 2. Typical Niagara Auto-Sluice installation.

Application Problems

To achieve the greatest advantages of the sluicing filter, the following conditions must be met or satisfactorily compromised by the filtration engineer.

Filter media must have long life or be replaceable at reasonable cost.
Permeability of media must remain nearly constant or be restored with reasonable chemical cost and time expended.
Cake solids must disperse within limits in the sluice liquor and separate freely from the medium and/or precoat.
Cake discharge must be effected with a minimum of sluice liquor; this reduces subsequent evaporation, dilution in process, or recycle volume for obvious reasons.
Media must be precoated in most cases with a suitable inexpensive material to maintain permeability and to separate cakes freely.
Discharged cake slurries must be effectively returned to the process, sewered as waste, or collected and processed at higher concentrations on a conventional filter for semidry discharge. In this sense the filter acts as a thickener. An example is cited in mainland sugar refineries where sluiced cakes are "sweetened-off" or washed on presses.
Sluice nozzle must be carefully engineered for the sluice liquor if other than water is used.

Sluicing filters, as a rule, are clarifying filters. They follow other primary separations of solids used in the earlier stages of processing. One such example is in the Ontario Paper Company's vanillin plant, where filters are employed to separate lignin solids. Cake slurries produced by sluicing are returned to Bird centrifugals, where the primary separation originated.

Engineering Refinements

To engineer these fundamentals into a filter station requires all the art of the filtration engineer. His efforts should be directed to:

Selecting a suitable medium of proper mesh or weave as related to the known type and volume per cent of solids and corrosion of prefilt liquors.
Actually testing conditions of sluicing if entirely unknown to obtain proper capacity of sluice nozzle when correlated to the full-scale effect of discharge.
Pilot testing average prefilt liquors to estimate optimum production rates as related to such critical factors as minimum cake thickness to effect discharge, fewest precoat materials per pound of product, and minimum size of equipment required for variations of filterability as examined or predicted from experience.

Development in the past 25 years of reasonably priced durable wire cloths in various meshes and many corrosion-resistant materials offers a wide selection in the search for the proper media. Synthetic cloths are continuing to widen their application in the filtration field, but problems exist in adapting them to sluicing filters. Many of the disadvantages of early filters stemmed from cloth media, which presented irregular surfaces to the sprays and involved rapid loss of permeability, requiring frequent replacement at high material and labor cost, as well as wear, shrinkage, and poor resistance to attack of many chemicals. Wire-cloth media lead in this application and offer the best possibilities in the search for the ideal medium.

Originally, sluicing filters were rather small (24-, 30-, and 36-in. tank diameters) and could be sluiced easily by manually directed streams. As sizes of the vertical pressure leaf filter grew, the bolted hand-wheel closure and height of the tank suggested automatic sluicing means to discharge cakes. The filters therefore now offer a quick-opening cover. Descriptions of various Niagara filter designs follow:

Niagara has a vertical tank with a dished bottom and cover which opens fully from a simple gasket ring. Leaves are vertically mounted on a filtrate header pipe extending across the tank shell near the bottom. A bottom discharge nozzle is installed with leaves provided with woven-wire cloth for precoat operation. Solids entering the leaf interior during cake discharge may thus be quickly drained away without being trapped. Leaf and manifold are joined with the familiar O-ring gasket seal. This is a well-known basic filter design.

In the Auto-Sluice design (5), the sluicing header is in the cover for model sizes up to and including 500 sq.ft. (see Fig. 3). The header is motivated by two external pneumatic motors linked to the pipe where it extends through chevron-packed glands and boxes on each side of the tank cover. One motor reciprocates the pipe, moving the two flat-nozzle sprays a distance of about 2 in. with the leaf centerline at the center of the movement. The other motor oscillates the pipe through a minimum angle to reach all cake in the leaf plane. This allows sluice liquor to contact all cake below when thickness is at least ½ in. Design of this mechanism is very similar to that of the original Sweetland manual sluicing device (1). Recently Sweetland has offered gear-motor operation of the sluice mechanism.

Stationary cover-mounted headers are also offered by Niagara which provide three nozzles between leaf spacing with overlapping sprays to obtain coverage of the exposed cake. An Enzinger Union stationary sluice header is illustrated in Figure 4. In this sluicing operation, the cake is drowned with large volumes of relatively undirected water; it has been successful for certain types of cake and where water or recycle volumes are not limited. Almost all sluicing filters provide two Pyrex 5-in.-diam. tank observers. These are located at two cake levels and between the largest leaves to permit inspection of discharge progress.

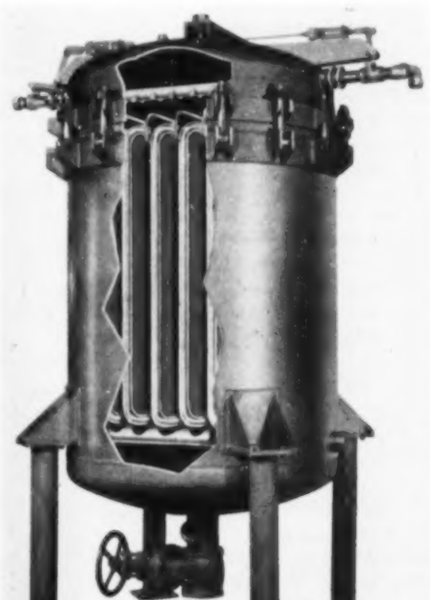


Fig. 3. Cut-away view of Niagara sluicing filter.

The largest Niagara sluice filter up to and including 1948 was 500 sq.ft. with a 48-in. tank. Maximum distance of spray travel in this design was 6 ft. to encounter the cake at the bottom of the leaf. Experience had shown that certain cakes did not respond to the low impact of the sluice liquor at such a distance. Consequently, to improve impact of present-size filters and even larger sized filters of 1,000 sq.ft. and 60-in. tank diameter, a major rearrangement of spray location was necessary. To combine the fabrication economy of the vertical tank design with a spray-nozzle location that could be more effective against stubborn cakes, later models have reverted to the example set by Merrill (1). Grommets are placed at or near the center of each filter leaf, through which a sluice pipe header large enough to carry up to 300 gal./min. is extended. Tank nozzles on each side carry the chevron packing and bearings. Rotation is provided by an external gear motor and suitable rotary joint. This locates the sprays more accurately at the cake and medium surface without obstruction, and operating distance is reduced to less than 4 ft. even for the largest sluicing filter. The sluicing distance is thus more comparable to that of other sluicing filters and retains the advantage of good discharge of cake solids from the tank after separation from the leaves.

Sluice-Liquor Volumes

Minimum volumes of sluice liquor are realized where the working distance is the shortest, all other conditions being equal. Design difficulties such as expelling cake from the tank, obstructions such as leaf frames, fixtures, or conduits interfering with the effective application of sprays, and bridging of freely separating cakes between leaves increase the amount of sluice water required for a given cake. Most filters will discharge cakes effectively within the limits of 1¼ to 2½ gal. of sluice liquor/sq.ft. of actual filter area. It is reasonable to suspect that where observation of sluicing progress is not possible, sluicing end points are unknown. Clean liquor issuing from the tank is no indication of clean discharge. Top-mounted motivated sprays of the Niagara Auto-Sluice will expend 3 to 4 gal./sq.ft. under the same conditions. Top-located stationary sprays will require 6 to 9 gal./unit area for the same conditions. Time-consuming hand sluicing will use 1 to 1½ gal. and is most effective since water may be accurately directed with least waste.

Spray-Nozzle Influence on Cake Discharge

Recent advancements in spray-nozzle engineering have provided designs especially suited to sluicing filters. This is in sharp contrast to early sluicing filters, which employed sprays produced by holes or slots in the header pipe or crudely formed sprays resulting from flattened pipe nipples threaded into the header (*1*). Nozzles are now available in a variety of materials, and the influence of liquor temperature, gravity, and viscosity on the spray pattern is better understood.

To minimize loss of unused spray water, well-engineered sprays must be directed at the surface covering the entire area of the leaf within the spray angle. Sprays must be able to get at the surface of the medium quickly by erosion of the outer cake layer, which will start peeling as the spray advances. This is followed by erosion of the cake and continued peeling as the operation progresses. Since leaf spacing in most sluicing filters is approximately 2 and 3 in. and spray distances are 30 to 46 in., location of the nozzle and spray pattern are most important design considerations.

For the variety of cakes encountered by sluicing filters, a single style of nozzle cannot be expected to produce optimum conditions of cake discharge for all sluice liquors. In the Niagara central design most applications may be handled effectively by flat sprays within an included angle of 10 to 25° maximum. Greater angles will require greater volume to provide the needed impact at the maximum working distance. Wide fan sprays at low volume have difficulty in equally distributing the water at elevated temperature, and droplet-particle size is sharply reduced, as is impact. Also, too much deflection of the sprays from one leaf surface to another on gummy-slimy cakes will tend to cause solids to adhere to the exposed medium, and eventual blinding may result. Consequently, one spray per surface is more effective in quickly breaking up the outer layers of the cake and rapidly peeling to completion of discharge. Selection of the proper nozzle for a given sluice condition will be necessary to produce the required impact. The following variables are helpful in selecting the proper nozzle:

Volume, or capacity, in gallons per minute varies directly as the square root of the head, in feet, at the header and should increase as the square of the working distance to produce minimum gallonage with adequate impact (6).

For sluice liquor other than water, capacity of the nozzle will vary inversely as the square root of the liquor gravity and as the viscosity (7).

Dispersion or erosion effect on cakes in most instances improves as the temperature of the sluice liquor is increased, since surface tension de-

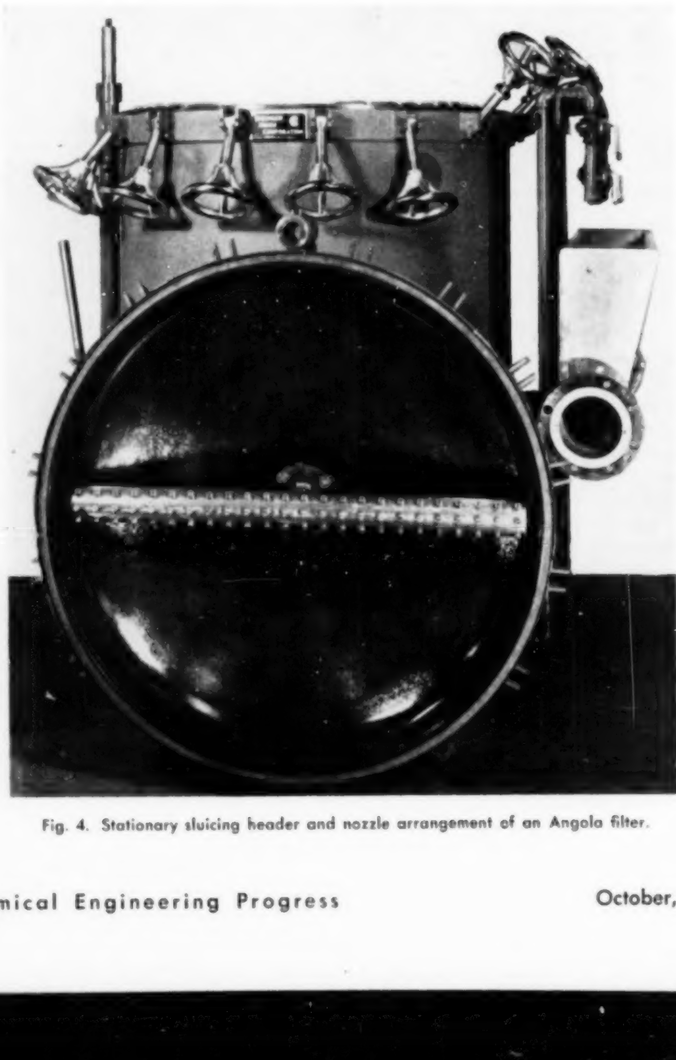


Fig. 4. Stationary sluicing header and nozzle arrangement of an Angola filter.

creases with rise in temperature. Correction to nozzle characteristics at elevated temperature is necessary as capacity decreases and spray angle increases (7).

Spray angles less than 25° have the least loss of impact as working distances are increased. The initial solid sheet of liquid issuing from the nozzle functions over a greater distance before breaking up into droplets. This provides the desired initial erosion and peeling of the cake.

With flat-spray nozzles of small capacity, 1 to 5 gal./min., droplet-particle size of water sprays approaches maximum at about 40 lb./sq.in., to produce good impact. Air resistance is less influential on the larger particles produced by lower initial velocities and relatively short working distances.

Favorable conditions of discharge of a certain stubborn cake are a function of nozzle capacity in gallons per minute to achieve minimum time and minimum sluice liquid.

High pressure at the nozzle with elevated temperature and/or low surface tension may cause atomization within the desired working distance. Loss of impact beyond the point of atomization causes incomplete leaf discharge and subsequent leaf blinding.

Helpful Techniques

A variety of methods if they can be used in operation of the filter station will assist the sluicing discharge of cakes. Any one or more of the following suggestions can be of importance in combating variables of cake resistance to sluicing discharge:

Additions of relatively short-fiber asbestos or paper to diatomaceous-earth precoats in a ratio of one part of fiber to ten parts of filter aid will improve cake discharge when solids are deposited on such sheetlike surfaces. Retention of the precoat will be further improved as will maintenance of the medium. Extra cost may be fully justified.

Cakes compacted by high filtering pressure may become extremely difficult to discharge consistently by sluicing. By limiting the pressure of cake building, such cakes may be effectively and economically handled. An adjustment in rates for this optimum pressure to produce the desired volume of filtrate will be necessary to obtain good cake discharge (8).

Hot sluice liquors can almost always be expected to produce sluicing economy when nozzle design is corrected to eliminate atomization within working distances.

Washed filter cakes originally containing high concentrations of prefilt liquors are always more easily eroded and discharged by sluicing.

Reduced sluice volumes can be obtained by partially discharging washed cakes with a tank full of wash water. Air agitation from a suitable distributor will partially reslurry cake solids as the filter is emptied. Sluicing sprays can then clean up the remaining cake with a minimum amount of water.

Reverse steam blowing through the leaves during sluicing with low-pressure steam 5 to 10 lb./sq.in. also may reduce sluicing volumes and maintain wire-cloth media.

As mechanical sluicing filters become more efficient in discharging cakes, higher capacities or rates of operation will be possible, as thin cakes need not be avoided.

Rotary vacuum primary separators in waste-disposal operations will function with less maintenance where clarity control is not limited and cloudy filtrates can be handled by sluicing filters and recycling slurries. Paper mills, plagued with white-water disposal, will find one answer in sluicing filters to produce clean filtrates for plant reuse and fiber recovery. Oil-seed solvent-extraction plants are seeking a totally enclosed filtration for miscella which will not require opening the filter. The sluicing filter when properly engineered can offer this industry smaller equipment and recycle of meal solids to the extractor to meet these exacting requirements. Offshore cane-sugar factories have expressed a need for filtration of the so-called "clear" and "cloudy" effluents from rotary cachaza filters. With the proper resolution of the requirements, it is possible to handle this work by means of sluicing filters directing cake slurries back to the drum filters. Research is now in progress to find a suitable filter aid, similar to the well-known bagicillio now used in conditioning cachaza from the clarifier, for separation on the drum filters. The advantages of this filtration are expected to be increased clarifier flows and improved raw-sugar purities, to name a few. These are new fields; yet existing installations of outmoded filters offer the greatest field for sluicing filters.

The newest proved development to come to the assistance of sluicing filters and to broaden the application horizon is instrumentation. Already a few installations of sluicing pressure leaf filters controlled automatically give promise of continued cost reduction without excessive capital outlay and with complete reliability. Automatic operation of cake washing is entirely flexible, and consistent results with this aid will increase advantages of the pressure leaf filter.

Literature Cited

1. Wright, Arthur, "Industrial Filtration," 1st ed., pp. 72, 73, 82, 170, 190, 245, 260, Chemical Catalogue Co., New York (1923).
2. Isacks, A. J., Southdown Sugars, Inc., Houma, La., private communication.
3. Ulrich, E. A., Sugar, **42**, No. 4, 22 (1947).
4. Hill, Graham, Taylor Instrument Companies, private communication.
5. Howland, E. H., and R. G. Tessmer, U. S. Patent 2,609,101 (September, 1952).
6. "Cameron Hydraulic Data," 10th ed., pp. 50-51, Ingersoll-Rand Company, New York.
7. Wahlin, F. W., and E. J. O'Brien, "Hydraulic and Pneumatic Spraying Manual," Spraying Systems Company, Bellwood, Ill., also private communications.
8. Tiller, F. M., "The Role of Porosity in Filtration," Vanderbilt University, private company research report (August, 1951).

Discussion

Charles P. Roberts (Westvaco Chemical Division, South Charleston, W. Va.): What has been your experience of the relationship in a given system between cake thickness and ease of washing? I'm thinking of a precoated system, of course. In some operations one can build up only a thin cake, but in a more favorable one he can build it thicker. Does that generally have a profound effect upon ease of sluicing?

E. A. Ulrich: It is true that thin cakes are more difficult to discharge than thick cakes, but in most cases thick cake solids have a tenacity or a cohesion one for another, and they have a pulling power. If you are not able to sluice the surface of the medium accurately with water sprays, the filter cake will pull away the material from the surface. Thin cakes will have to have very accurately directed sprays in order that the peeling effect will clean the medium. This is the most important feature in cake operation, because one must be able to clean that medium and maintain it at reasonably permeable condition.

Presented at Forty-fifth annual meeting, Cleveland, Ohio.

ABSTRACTS

(Continued from page 560)

may be calculated in a simple and reproducible manner from the analysis of the mixture and an A. S. T. M. distillation of the heavy ends.

Chem. Eng. Progress Symposium Series, **49**, No. 6, 81 (1953).

Graphical Interpretation in Ternary Distillation

Kwo-Tseng Lee and Karl Kammermeyer
State University of Iowa

A graphical method of correlating the equilibrium liquid and vapor compositions for the ternary system, applicable to both ideal and nonideal systems, has been developed. For ideal systems, equations representing the ternary equilibrium curves have been derived which facilitate the construction of the auxiliary diagrams of any two components to carry out the suggested graphical procedure. This graphical correlation and the well-known concept of addition and difference points simplify the solution of ternary-distillation problems.

Chem. Eng. Progress Symposium Series, **49**, No. 6, 99 (1953).

TITANIUM REFERENCE SHEET

W. W. HARPLE, and G. KIEFER
Allegheny Ludlum Steel Corp.
Brackenridge, Pa.

T. K. REDDEN
Titanium Metals Corporation of America
Henderson, Nev.

APPLICATION AND REMARKS: Applications where titanium is now being used as a construction material are limited because of the high cost of the metal. Even with this high initial cost, it has been used in instances where it was shown to outperform other materials to such an extent that savings were realized. Titanium is well known for its immunity to corrosive marine environments, its resistance to nitric acid, ferric chloride and other chloride salts and wet chlorine. Encouraging results have been obtained in greatly improving the corrosion resistance of titanium in HCl and H_2SO_4 by the addition of oxiding agents or inorganic sulfates. The resistance of titanium to many common pitting agents is outstanding. Ferric chloride, cupric chloride and sodium hypochlorite do not cause pitting of titanium. The addition of carbonaceous material does not accelerate pitting. Titanium also appears to have the same resistance to crevice corrosion as to pitting. Titanium has been shown to be immune to stress corrosion cracking in most media with the exception of red fuming nitric acid.

HEAT TREATMENT: Titanium metal is furnished to customers in the annealed conditions, unless some other condition is requested. Annealing after cold-forming may be accomplished by heating at 1300° F. for one hour per inch of thickness.

WELDABILITY: Titanium metal may be resistance welded or fusion welded by the inert gas arc method. With fusion welding the most important factor is proper shielding to prevent contamination of the weld by oxygen and nitrogen which can cause embrittlement.

ALLOY—TITANIUM METAL

Nominal Composition (Titanium Metals Corp., Grade Ti 75A):

Carbon	0.05% maximum
Iron	0.12% maximum
Nitrogen	0.08% maximum

Mechanical Properties:

Tensile strength	80,000 to 110,000 lb./sq. in.
0.2% yield strength	70,000 to 95,000 lb./sq.in.
Elongation 2 in.	20-30%
Hardness	200-240 B. H. N.
Bend angle	180° Diam. 3 x T

Sizes and Shapes—Most commercial sizes of bar, forgings, sheet, strip, plate, and wire can be furnished.

CORROSION RESISTANCE

ACIDS

Acetic, Glacial, Boiling	A
Aqua Regia, (3:1), 70°	A
Chromic, 20%, 70°	A
Citric, saturated solution, 70°	A
Formic, 87%, boiling	A
Formic, 50%, boiling	C
Hydrochloric, less than 3%, 100° [1]	A
Hydrochloric, 4%-10%, 100°	B
Hydrochloric, 10%-37%, 100°	C
Hydrochloric, less than 1%, 150°	A
Hydrochloric, 2-4%, 150°	B
Hydrochloric, 5%, 150°	C
Hydrochloric, 20%, 150°	D
Hydrochloric, less than 1%, 175°	A
Hydrochloric, 2%, 175°	B
Hydrochloric, 3-5%, 175°	C
Hydrochloric, 20%, 175°	D
Hydrochloric, ½%, 200°	A
Hydrochloric, 1%, 200°	B
Hydrochloric, 20%, 200°	C
Hydrochloric, 3-5%, 200°	D
Hydrochloric, 10%, 200°	E
Hydrofluoric, 1%, 70°	E
Lactic, 87%, boiling	A
Nitric, 65%, boiling	A
Nitric, white fuming, 70°	A
Nitric, red fuming, 70° [2]	A
Oxalic, saturated solution, 70°	C
Phosphoric, 10%, 100°	A
Phosphoric, 10%, boiling	D
Phosphoric, 85%, 100°	C
Sulfuric, below 3%, 100° [3]	B
Sulfuric, 4-30%, 100°	C
Sulfuric, 50%, 100°	D
Sulfuric, above 50%, 100°	E
Sulfuric, ½%, 150°	B
Sulfuric, 1-5%, 150°	C
Sulfuric, 20%, 150°	D
Sulfuric, above 20%, 150°	E
Sulfuric, below 1%, 175°	C
Sulfuric, 2-5%, 175°	D
Sulfuric, above 20%, 175°	E
Sulfuric, ½-5%, 200°	D
Sulfurous, 6%, 70°	A

ALKALIES AND ALKALINE SALTS

Ammonium hydroxide, 28%, 70°	A
Sodium carbonate, 20%, boiling	A
Sodium hydroxide, sat'd. soln. 70°	A

SALTS

Sodium chlorate, sat'd. soln.	A
Sodium nitrate, sat'd. soln.	A
Sodium phosphate, sat'd. soln.	A
Sodium bisulfate, sat'd. soln.	A
Sodium sulfide, sat'd. soln.	A
Sodium sulfite, sat'd. soln.	A
Sodium cyanide, sat'd. soln.	A
Sodium dichromate, sat'd. soln.	A

All salt solutions at 70° F.

MISCELLANEOUS

Iodine-Alcohol, soln. 70° [4]	—
Phenol, sat'd. soln. 70°	A
Alcohol, 70°	A
Benzene, 70°	A
X-ray developer soln. 70°	A
Sea water 70° [5]	A
Salt spray, 20%, 90° [5]	A
Ferric chloride, 10%, 70° [5]	A

All temperatures Fahrenheit

[1] The addition of small amounts of an oxidizing agent such as chromic acid or copper sulfate will greatly increase usefulness of titanium in hydrochloric acid.

[2] Red fuming nitric acid produces stress corrosion cracking of titanium. Prolonged exposure also produces increasing corrosion rates.

[3] The addition of small amounts of an oxidizing agent or various inorganic sulfates will greatly increase the usefulness of titanium in sulfuric acid.

[4] This solution produces violent pitting in a matter of a few hours.

[5] Sea water, salt spray and ferric chloride do not produce pitting on titanium in contrast to the rapid pitting effect on many metals.

RATINGS:

A—0.005 maximum in. penetration/yr.
B—0.005—0.042 in. penetration/yr.
C—0.042—0.120 in. penetration/yr.
D—0.120—0.420 in. penetration/yr.
E—0.420 minimum in. penetration/yr.

No. 26

Meet Me in St. Louis

Article prepared by Richard G. Kerlin, Mallinckrodt Chemical Works, St. Louis, Mo.

Left to right: A. J. Pastene, Monsanto Chemical Co., vice chairman; T. J. Stewart, C. K. Williams & Co., vice chairman; J. J. Healy, Jr., Monsanto Chemical Co., cochairman, Program Committee.

A record attendance of more than 2,000 is expected for the Forty-Sixth Annual Meeting of the A.I.Ch.E. to be held in St. Louis, Mo., Dec. 13-16, 1953, with headquarters at the Hotel Jefferson. Charles W. Swartout, Mallinckrodt Chemical Works, general chairman of the meeting, expects it to be even more popular than the 1937 and 1944 annual meetings in St. Louis; these and the 1947 meeting here drew from a wide area.

A comprehensive program is being planned with attractive features for members, ladies, friends, and students. Conspicuous among the activities are nine technical symposia, a seminar, the Fifth Institute Lecture, presentation of the Professional Progress Award, eighteen plant trips—all synergized with a well-rounded entertainment program.

Registration and Information

Preregistration is strongly recommended for this meeting because attendance is limited for some events. Richard J. Kozacka, Monsanto Chemical Co., chairman of the Registration Committee, has announced that a streamlined registration procedure will assure preferential and speedy processing for preregistrants. A card for this purpose will be enclosed in the program announcement sent to each member. Registration will be on the Mezzanine of the Hotel Jefferson and the hours will also be specified on the program.

An information center will function nearby on the Mezzanine throughout the meeting. Here participants may flip through the directory of registrants, inquire about details of program and plant trips, pick up tips on local attractions, exchange messages and check on "lost and found." Other communication points will be General Headquarters (East Room), the Press Room for newspaper, magazine, radio and television publicity (East Room) and Ladies' Headquarters (Room 3).

Housing

Single rooms are always at a premium. Robert E. Lenz, Monsanto, Housing Committee chairman, therefore requests that members double up if

Left to right: Richard M. Lawrence, Monsanto Chemical Co., cochairman, Program Committee; Charles W. Swartout, Mallinckrodt Chemical Works, general chairman.

possible. To do this, *one* hotel reservation card should be sent in with both names on it. As only part of the available rooms will be at the Jefferson, reservation cards should be sent in at the earliest possible date. Confirmations will be sent within 24 hours by the hotel assigned. However, any cancellations or changes should be sent to the Hotels Convention Reservation Bureau, Room 406, 911 Locust Street, St. Louis, Mo. The Bureau saves cancellations for A.I.Ch.E. registrants, but the hotels individually do not. Although the Hotel Jefferson will be most in demand, the others are within a few blocks. Price schedules can be found in the program.

Seminar on A.I.Ch.E. Questionnaire

Frank R. Fisher, Sinclair Research Laboratories, will moderate a general discussion to develop results of the A.I.Ch.E. Questionnaire on Institute policies and professional status of members. Some results were reported in "C. E. P." for April, July, and September, 1953. The seminar will be held in the Gold Room of the Hotel Jefferson, from 2:00 to 5:00 p.m., Sunday, Dec. 13.

Getting on Stream

The proceedings of the Forty-Sixth Annual Meeting will get underway Monday morning in the Gold Room when A.I.Ch.E. President W. T. Nichols introduces Mayor Raymond R. Tucker, the engineer famed for killing smog in St. Louis, who will extend the official greetings of the City of St. Louis. The annual business meeting will then be held, preceding the Fifth Institute Lecture.

Fifth Institute Lecture

George Granger Brown, dean of the College of Engineering at the University of Michigan, will deliver the Fifth Institute Lecture in the Gold Room at 11:00 a.m., Monday, Dec. 14. He will talk on some aspects of thermodynamics as applied to chemical engineering. Dr. Brown, also a director of Nash-Kelvinator Corp., is now Treasurer of A.I.Ch.E. He served as President of the Institute in 1944 and won the William H. Walker Award in 1939.

Institute Lectures are the oral counterparts of review articles—authoritative, informative and up to date. They are published later, usually in expanded form, in the Chemical Engineering Progress Monograph series.

Awards Banquet . . .

The Awards Banquet, highlight of the program, will be held Tuesday evening in the Gold Room. A principal feature will be presentation of medals and prizes to the winners of the Institute's various awards, which are described below. There will be no long speeches. Institute officers are to be formally relieved of their offices and newly elected officers and directors will be introduced and installed.

There will be cocktails before dinner and dancing afterward in the Ivory and Crystal rooms. Dress is to be optional.

. . . And The Awards

PROFESSIONAL PROGRESS IN CHEMICAL ENGINEERING AWARD

The presentation at this year's banquet will be the sixth recognition of an outstanding chemical engineering contribution leading to the betterment of human relations and circumstances. Sponsored by the Celanese Corporation of America and administered by the Institute, the certificate of the award is accompanied by $1,000.

Preprints

Preprints of the papers in the Heat Transfer, and Distillation Symposia will be available at twenty-five cents each. Members will receive order blanks with the program of the meeting. They will be mailed from the Secretary's office in time to give engineers ample opportunity to study the articles before presentation.

WILLIAM H. WALKER AWARD

Given in memory of the late Prof. William H. Walker of the Massachusetts Institute of Technology, who pioneered in the development of modern chemical engineering principles, this award consists of a certificate and plaque. The 1953 award will be the eighteenth for Institute-published papers of outstanding quality, clarity of expression and practical utility. Prof. J. Henry Rushton, Illinois Institute of Technology, was thus honored last year for his many papers.

JUNIOR MEMBER AWARD

Limited to Junior members of A.I.Ch.E., this award parallels the William H. Walker Award.

A. McLAREN WHITE AWARD FOR A.I.Ch.E. STUDENT CONTEST PROBLEM

The Committee on Student Chapters has for twenty-two years directed competition for prize-winning solutions to the annual student problem. Prizes are the A. McLaren White Award of $200 for first place, $100 for second, $50 for third and certificates of honorable mention for a few others. At last year's Awards Banquet, first, second, and third prizes, respectively, went to Harold F. Hublein of the Du Pont Co., Rodney A. Nelson of the University of Minnesota, and David G. Stephan of Ohio State University, for engineering design of an atomic power plant.

Technical Program

The technical program is so comprehensive that members may choose from among three symposia to be held simultaneously each half-day from Monday afternoon through Wednesday afternoon, in the Gold, Crystal, and Ivory Rooms. Program arrangements are the work of Richard M. Lawrence and John J. Healy, Jr., both of Monsanto, successive chairmen of the technical program. Topics range from such broad fields of chemical engineering as distillation, drying, and heat transfer through aspects like productivity, dust and mist collection, and waste disposal to the specialized subjects of carbonization of oil shale and coal and the chemical engineering use of electronic computing machines. Among papers of particular interest will be one titled "Yardsticks of Productivity and the Use of Productivity Concept in Industry" by Ewan Clague, head of the Bureau of Labor Statistics, and another, "Opportunities for Chemical Engineers in the Steel Industry" by Thomas F. Reed, U. S. Steel Corp.

Student Program

This year's student program, under the chairmanship of Willard P. Armstrong of Washington University, is expected to attract a sizable number of chemical engineering students from several states in the St. Louis region. The program will continue for two days, Monday and Tuesday, in Room 1. Designed for good balance, it alternates between morning sessions of student papers and afternoon panel discussions by engineers from several industries and education. The panel discussions are entitled "What Career Will You Choose?" and "The Transition from the Scholastic World to the Industrial World." Additional features are a student party Monday evening and a luncheon Tuesday at Carl's Rio Room, at which "Professional Development" will be discussed. A prize of a $25 U. S. Savings Bond will be awarded for the best student paper presented.

(Symposia subjects and list of plant tours on page 44)

San Francisco cable cars salute the visiting chemical engineers.

By the Golden Gate

General view of the Sunday evening Get-Together in the Gold Room of the Fairmont Hotel.

Rain fell in the Tonga Room, during the Mexican luncheon.

Left to right: Russell C. Phillips and Nevin K. Hiester, both of Stanford Research Inst.; John A. Whitcombe, University of Michigan; J. T. Banchero, University of Michigan; Raymond K. Cohen, Stanford Research Inst.; Robert M. Wheaton, Dow Chemical Co.; J. Ben Rosen, Princeton University, and Theodore K. Vermeulen, who presided over the symposium on ion exchange.

San Francisco's famed cable cars blazoned forth with signs last month in a welcome to chemical engineers and the chemical industry in general. With its famed western hospitality San Francisco was putting on a show for the 792 representatives who registered during the week of Sept. 13 at the Fairmont Hotel for an A.I.Ch.E. national meeting.

The local committee planned very few formal evenings for the A.I.Ch.E., but because of the nature of the city no one missed them. Between being amazed at the view from the top of the Mark or from Telegraph Hill and puffing up and down the perpendicular streets of San Francisco, the chemical engineers had little time to worry about formal dinners, luncheon speakers, or planned programs.

Earnest groups in halls and lounges might as easily have been discussing the relative merits of abalone steak vs. sukiyaki, as they might have been the H.T.U.'s of new packings, or the efficiency curve of a new pump.

But the cable cars were not the only sign that San Francisco knew chemical engineers were meeting. Department stores of San Francisco prepared special windows relating to chemically produced merchandise; synthetic fibers, detergents, glass fishing rods, and other displays made their appearance. Television shows, radio programs, newspaper columnists and service clubs all blossomed out with special efforts aimed at the chemical engineer. The only formal program was a Mexican luncheon at the Fairmont, featuring a representative of the Chamber of Commerce who showed the chemical industry was one of the earliest endeavors in the Bay area. This prompted President Nichols to remark, as he thanked the local committees for their words and hospitality, "that in the San Francisco area chemical engineering was next to the oldest profession."

The committee weighing the techniques of giving papers was headed by David I. Saletan, and the award winner was David W. Schroeder, who was judged to have presented his paper "The Heats of Vaporization of a Binary Mixture" in the best manner.

Technical Discussion

A peacetime application of atomic energy to a chemical engineering process was among the many operations considered. Melbourne L. Jackson of the University of California described the use of radioactive tracers in measuring complex liquid flow. Minute amounts of tracer were introduced into the liquid stream, and the resulting radiation was detected by means of a Geiger counter. The radiation intensities were then used

(*Continued on page 22*)

E. B. Chiswell, left, Calif. Research Corp., presided at a general technical session. Speakers were Lloyd Berg, Montana State College.; Julius H. Bochinski, Iowa State College; Frank Fowler, Midwest Research Inst.; and Clyde Berg, Union Oil of Calif.

Left to right: A. S. Michaels, M.I.T.; Burton V. Coplan, Knolls Atomic Power Laboratory; J. P. Sachs, Illinois Inst. of Tech.; J. H. Rushton, Illinois Inst. of Tech.; Edgar L. Piret, University of Minnesota. The session was on mixing.

J. L. Franklin, H. G. Drickamer, C. F. Curtiss and C. R. Wilke took part in a program on transport properties.

Left to right: Charles Nelson, who presided over a general technical program; John R. Kyte, University of Minnesota; Morris Eisenberg, University of California; Jack E. Coppage, Stanford University; Charles R. Wilke, University of California; and C. W. Tobias, University of California.

Marvin W. Larson, The B. F. Goodrich Chemical Co.; Lee Van Horn, The Fluor Corp. Ltd.

George C. Gester, Jr., San Francisco meeting cochairman, opens the first session.

Left to right: T. E. Drisko, Jr., Dow Chemical Co., and Hotel & Meeting Room committeeman, W. H. Thomas, Ethyl Corp.; T. D. Skaggs, Ethyl Corp.; and Mrs. T. E. Drisko, Jr., Ladies' Program Comittee.

J. H. Rushton, Illinois Inst. of Tech.; Robert C. Gunness, Standard Oil Co. (Indiana); R. S. Ray, Shell Chemical Corp.; C. A. Stokes, Godfrey L. Cabot, Inc.

GOLDEN GATE

(Continued from page 20)

to calculate the characteristics of the flowing fluid. Disturbances ordinarily resulting from physical contact between the fluids and the measuring device were thereby eliminated.

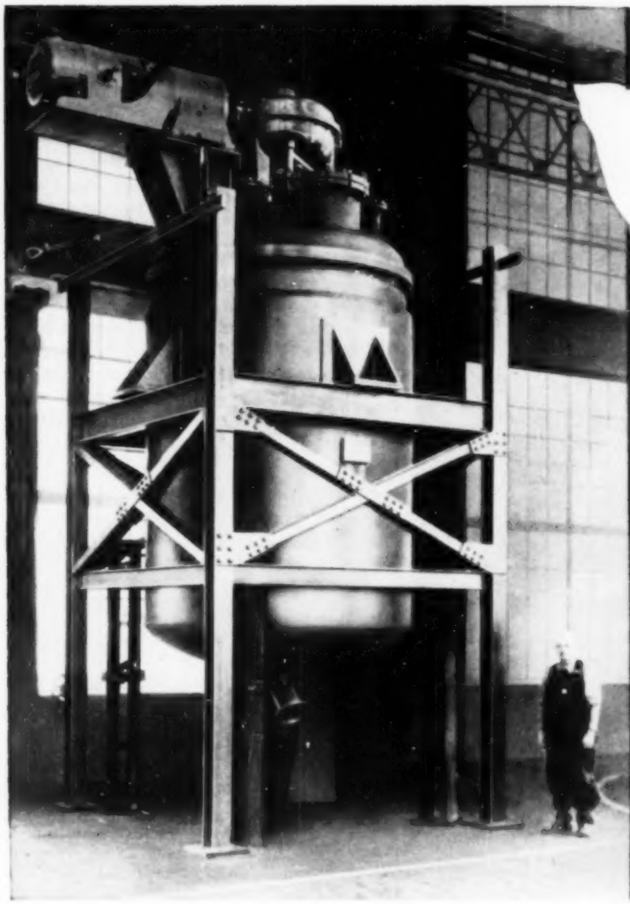
Continuing interest in ion exchange was reflected in the symposium presided over by N. R. Amundson of the University of Minnesota and Theodore Vermeulen of the University of California.

The separation of rare earths by ion exchange was explained by F. H. Spedding and J. E. Powell of Iowa State College, who used a single continuous elution process. The cost of chemicals and water was low, according to Dr. Powell, because the effluent solution was restored to its original *p*H with ammonia and recycled repeatedly.

The economic factors in ion exchange were discussed in several of the papers. Nevin K. Hiester, Raymond K. Cohen, and Russell C. Phillips of Stanford Research Institute pointed out that a reduction in investment could be realized for some industrial operations, such as the large-scale removal of minerals from water, by use of moving beds of ion-exchange resin instead of cyclic operation of fixed beds. W. C. Bauman of Dow Chemical Co. also discussed the relative economics of batch and continuous operation.

One of the papers on economics, by E. B. Chiswell and J. J. Merrill of the California Research Corporation, concerned the capital costs for a petrochemical project. The authors showed how tax rates altered circumstances when new processes in the chemical field were considered. They claimed that the type of plant a manufacturer might put in for the production of ethylene oxide could be seriously influenced by the tax bracket. The two processes which the authors compared were the chlorohydrin process and the direct oxidation of ethylene with air. Calculating a cost of six million dollars for a plant to produce thirty million pounds of ethylene oxide a year by the direct oxidation method and of three million dollars for one of similar capacity using the chlorohydrin method, the authors stated that in a situation of no taxes the total cost of ethylene oxide by the direct oxidation route would be two cents a pound less than by the chlorohydrin route, considering a four-year pay-out period. If the tax rate is increased to 50 per cent, the situation does not change; the direct-oxidation route is still cheaper but only by a slight amount. When the situation is altered so that the producer is required to pay in the higher tax bracket

(Continued on page 24)



BUFLOVAK Steam Jacketed Kettle, 2750 gals. Speeds the production of a high quality grease for a nationally-known company.

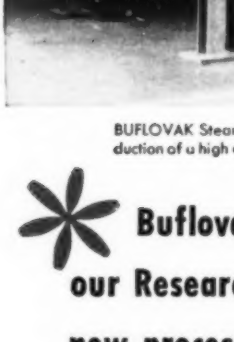
Your Kettle Performance is worth investigating

DO YOU...

want to save time?
cut costs?
make better products?

Buflovak Kettles available in our Research Laboratories to test new processes . . . new products!

New and untried processes frequently present unexpected problems. The safest procedure is to process a quantity of the product and observe the results. Such facilities are available in the BUFLOVAK Research and Testing Laboratory. Results show *positively* what is needed for your processing. Kettles can then be designed and built to most economically and profitably fulfill your expected requirements.



Free! **48-PAGE COLOR BOOKLET**

. . . So detailed it is literally a handbook on Heating . . . Cooling . . . Drying, etc.

You can save time, cut costs, and make better products, by using BUFLOVAK Kettles in your processing. BUFLOVAK Kettles have proved to be a vital part in processing operations . . . and operations can be progressively performed in the same unit, thus speeding up production, lowering investment costs, and increasing profits.

BUFLOVAK Kettles perform a number of very basic operations: heating, cooling, mixing, extracting, reacting, distilling, evaporating, drying, and solvent recovery. Vacuum, atmospheric, or pressure operations can be provided.

Kettle sizes range from the one gallon laboratory size to massive units. Illustrated above is a 2750-gal. kettle.

Positive mixing and thorough cleaning of the heating surface is provided by eight distinct types of agitators with modifications to meet the individual need.

Yes, you will profit, as are so many varied industries today, by specifying BUFLOVAK Processing Kettles.

BLAW-KNOX COMPANY
Buflovak Equipment Division

1567 FILLMORE AVE., BUFFALO 11, N.Y.

GOLDEN GATE

(*Continued from page 22*)

of 80 per cent, the cost of the product is reversed and ethylene oxide from the chlorohydrin process is considerably cheaper than that from direct oxidation. When the same analysis was applied to plant size, the two authors found that building larger plants is by no means a general solution to the problem of obtaining a cheaper product. Since, as the authors point out, there is a greater risk in building a larger plant inasmuch as a greater share of the total market is required to absorb the product, investors may require a shorter pay-out period. It is this rapid pay-out period, plus the tax structure, which may make a larger plant less economical than the smaller plant.

The choice of method of manufacturing and purifying synthesis gas for ammonia production may very well be the clue to more profitable operation in the opinion of B. J. Mayland, E. A. Comley, and J. C. Reynolds of The Girdler Co. They spoke to the chemical engineers about "Economic Evaluation of the Production of Ammonia Synthesis Gas from Natural Gas" and stated that whenever a new ammonia plant is contemplated it is necessary to consider various methods for carrying out individual steps in order to arrive at the most economical processing scheme. For a 120-ton-per-day anhydrous ammonia production the authors, through the use of an air partial-oxidation method at elevated pressures (350 lb./sq.in.g.), showed operating costs of four dollars a ton less than for the conventional low-pressure ammonia synthesis.

The authors studied possible improvements in the manufacture of ammonia. Usually some form of primary and secondary reforming with steam over a catalyst is used. The authors, however, investigated the case of the conventional process at elevated pressures, the elimination of the primary furnace by partial combustion with air at low pressure (45 lb./sq.in.g.), and partial combustion with air at elevated pressures (350 lb./sq.in.g.) The operation of the conventional process at higher pressures (150 lb./sq.in.g.) resulted in a saving of about fifty cents a ton; the air partial oxidation at low pressure turned out, in their analysis, to be even more expensive than the conventional method. The most favorable case, air partial oxidation at elevated pressure, gave a saving of four dollars a ton.

M. J. P. Bogart and J. H. Dodd of The Lummus Co. compared the costs of manufacturing acetylene by two different processes. In the regenerative

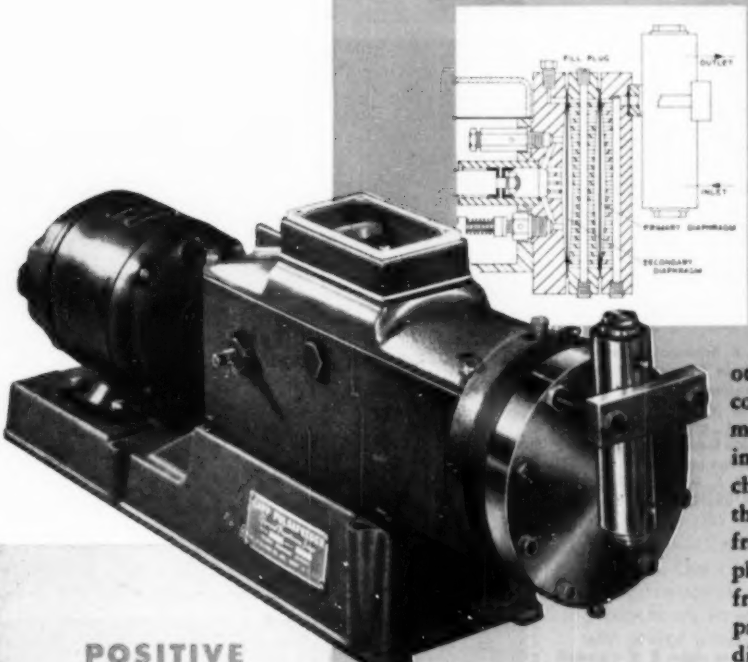
(*Text continued on page 28*)
(*More pictures on page 26*)

YOU CAN PUMP *Liquid Chlorine*

AND OTHER FLUIDS REACTIVE TO PETROLEUM OILS

with Lapp PULSAFEEDER

DOUBLE-DIAPHRAGM CONSTRUCTION



This is one of several "special design" models of Lapp Pulsafeeder, specifically engineered to the requirements of controlled-volume pumping of "hard-to-handle" chemicals. It is of double-diaphragm construction which provides certain protection in the pumping of anhydrous liquid chlorine, anhydrous hydrogen fluoride, high concentration hydrogen peroxide, fluorine gas or other chemicals which are reactive in contact with petroleum oils. A primary diaphragm isolates chemical being pumped from an intermediate chamber containing a liquid inert to the chemical, which is in turn isolated from hydraulic oil by a second diaphragm. Protection of process liquor from hydraulic oil and atmosphere is provided, even in the case of failure of diaphragm from corrosion fatigue.

POSITIVE CONTROL OF PUMPING VOLUME

Lapp Pulsafeeder is the combination piston-diaphragm pump for controlled-volume pumping of fluids. Reciprocating piston action provides positive displacement. But the piston pumps only an hydraulic medium, working against a diaphragm. A floating, balanced partition, the diaphragm isolates chemical being pumped from working pump parts—eliminates need for stuffing box or running seal. Pumping speed is constant; variable flow results from variation in piston-stroke length—controlled by manual hand-wheel, or, in Auto-Pneumatic models, by instrument air pressure responding to any instrument-measurable processing variable.

WRITE FOR BULLETIN 300 with typical applications, flow charts, description and specifications of models of various capacities and constructions. Inquiry Data Sheet included from which we can make specific engineering recommendation for your processing requirement. Write Lapp Insulator Co., Inc., Process Equipment Division, 32 Wilson Street, Le Roy, New York.

W. T. Nichols (President, A.I.Ch.E.), Monsanto Chemical Co.; Mrs. R. F. Moran.

Mrs. W. Hirschkind (Ladies' Committee) and Mr. Hirschkind, The Dow Chemical Co.

Left to right: Wayne C. Edmister, California Research Corp.; W. N. Lacey, dean, Graduate School, Calif. Inst. Tech.; and Mott Souders, Jr., Shell Development Co.

Left to right: Mrs. Charles Nelson; José Samaniego, Shell Development Co., and chairman of the Entertainment Committee; Mrs. José Samaniego, Ladies' Program Committee, and Charles Nelson, Shell Development Co. and a Director of A.I.Ch.E.

L. F. Schimansky, left, California Research Corp. and chairman of Registration, was pleased with the 792 total attendance. Seated with him is a fellow registration committeeman, Richard J. Mitchell of California Research Corp.

Left to right: E. B. Chiswell, California Research Corp.; B. J. Mayland, The Girdler Co.; M. J. P. Bogart of Lummus Co., and R. Paul Kite of the Dorr Co. Mr. Kite was chairman of this symposium, which discussed the economic evaluation of chemical projects.

D. W. Schroeder, second from left, won this meeting prize for the best presented paper. He and John A. Tallmadge, left, are both of Carnegie Tech. W. N. Lacey, center, was chairman of this Symposium on Applied Thermodynamics. J. H. Ashley, Northwestern Tech; and David B. Todd, Princeton University.

GOLDEN GATE

(Continued from page 24)

process some gas is burned and used to heat a bed of ceramic material, and this bed is then used to heat a separate mass of gas to the cracking temperature. In the partial-combustion process some of the natural gas is allowed to burn partially in air to raise the temperature of the unburned portion to the desired level. This basic difference in the two processes, it was made clear, also affects the design of other sections of the plant.

New Tower Packing

A new tower packing for diffusional operations was introduced to the chemical engineers at San Francisco by A. J. Teller of Fenn College, Cleveland, Ohio. The new tower packing, which is actually a helical torus, or, as Dr. Teller explained in lay language, "a multiple helix in the form of a doughnut," was designed on the theory that if a packing causes high interstitial holdup, high efficiencies of transfer would result owing to 1) an increased interstitial holdup which would cause the liquid to remain in the column for a longer period and give an increased material-transfer contact time; 2) an interstitial build-up of liquid in the column which would restrict the paths of flow available to the gas and increase higher local velocities with an attendant increase in transfer weight. Further, said the author, a longer and more tortuous path for the gas phase would increase the effective column length for mass transfer, with resulting lower H.T.U.'s.

A further objective of the search, according to Dr. Teller, was to obtain a packing that upon being dumped into a column would afford a maximum of surface-edge contacts and have high interlocking properties. The sizes that Dr. Teller used for the tests were 3/4 by 2 in. and 1/2 by 1 1/4 in. Nine helical turns were used per unit, the rosettes being made of polyethylene strip to obtain nonwetting properties.

Dr. Teller evaluated the packing performances of the new rosettes by the absorption by city water of ammonia from low concentrations in air. In a packing-efficiency comparison for liquid flow rates from 2,500 lb./hr.(sq.ft.) down to 500 lb./hr.(sq.ft.) the height of a transfer unit in feet varied only from about 0.7 to 0.9. These results, however, were for a lined tower, a technique the author used to overcome the preferential wetting of the glass wall by the water. The lining of the column was polyethylene with an average thickness of 0.09 in. In an unlined column the same liquid rates showed variations in H.T.U. from about 1.0 to 1.6 ft.

Dr. Teller's results were presented in a series of graphs, and Chemical Engineering Progress hopes to print the paper in full before the end of this year.

Publicity Committee, left to right: D. F. Rynning, Shell Development Co.; Gordon Foster, Shell Development Co.; and publicity cochairman N. K. Hiester, Stanford Research Inst.

Bryant Fitch, The Dorr Co.; Jesse Coates, Louisiana State University.

Robert I. Stirton, Oronite Chemical Co.

A. E. Handlos, Shell Development Co.

Jack E. Powell, Iowa State College.

J. T. Moody, Humble Oil & Refining Co.

J. J. Martin, Univ. of Mich., and Mrs. Martin; R. L. Moison, Du Pont Co.

Left to right: N. R. Amundson, who presided over a symposium on ion exchange; R. L. Moison, Du Pont Co.; Joseph L. McCarthy, University of Washington; W. C. Bauman, Dow Chemical Co.; and J. Ben Rosen, Princeton University.

R. W. Moulton, left, presided at a general technical program. Papers were presented by George E. Alves, Du Pont Co.; A. J. Teller, Fenn College, and Harshaw Chemical Co.; Edgar H. Hoffing, M. W. Kellogg Co.; Lloyd Brownell, University of Michigan, and R. R. Kraybill, University of Rochester.

LeRoy A. Bromley, University of California; Ralph E. Peck, Inst. of Gas Technology; R. L. Wentworth, M.I.T.; Mott Souders, Jr., who presided over the Transport Properties Symposium and served on the Program Committee, and Norman Carr.

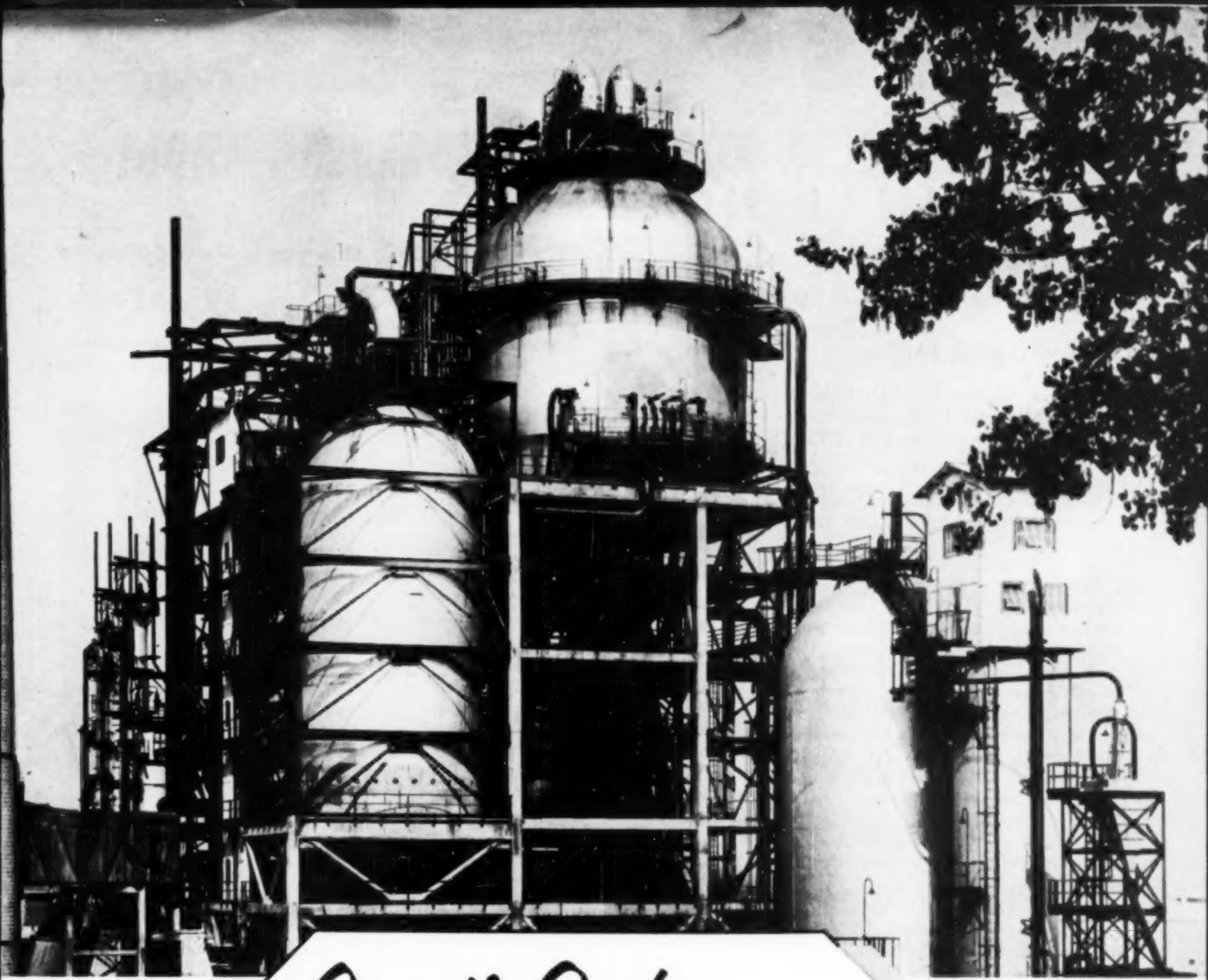


Photo Courtesy The Texas Company

MARGINAL NOTES

News of Books of Interest to Chemical Engineers

Classical Nuclear Physics

Theoretical Nuclear Physics. John M. Blatt and Victor F. Weisskopf. John Wiley & Sons, New York (1952), 864 pp. $12.50.

Reviewed by Richard N. Lyon, Oak Ridge National Laboratory, Oak Ridge, Tenn.

This book is a lucid description of the theories which have been proposed to explain what is known at present about atomic nuclei and their behavior. Since no comparable book has been written in this field, the authors have performed a notable service in collecting the facts, and in providing such an understandable presentation of the current theories. This book is recommended to any person who has a moderate knowledge of quantum mechanics and who is interested in obtaining a clear understanding of nuclear physics in its present stage of development.

By "theoretical nuclear physics" the authors mean "the theoretical concepts, methods and considerations which have been devised in order to interpret the experimental material and to advance our ability to predict and control nuclear phenomena." With the exception of one chapter on nucleon-nucleon scattering, the discussion is limited to energies below 50 M.E.V., discussions of nuclear phenomena associated with cosmic rays and with mesons being excluded. The theory of nuclear reactors, the slowing down of neutrons, and the stopping of charged particles in matter have also been omitted, because these are considered by the authors to be in the realm of nuclear engineering rather than that of nuclear physics. The discussion of nuclear fission is limited, because many relevant facts are still unavailable for general dissemination. The subject of the book may be described, therefore, as classical nuclear physics.

The authors have taken great pains not to lose the reader. Wherever possible, the theories are expressed in clear mechanical terms and the mathematics is used only to reinforce the written discussion. The terminology is carefully defined. Sections of unusual difficulty are marked with a special symbol so that they can be skipped by casual readers. Engineers without training in quantum mechanics will find many sections which will be quite clear because of the careful, lucid style in which the book is written.

The reader of this book feels lifted along in a way which is unusual in an advanced technical text. Part of this is due to the unpretentious style, which results in the clear and considerate exposition. The writing style also results in the reader's identifying himself with the investigators in the field, so that nuclear physics becomes an extremely interesting unfinished story.

Tables and plots of nuclear data occur in the text where pertinent, and thirty pages of the book are required to list the numerous references which are cited. The index is complete and well organized. The table of contents is broken down by sections which make any topic easy to find.

Several good elementary texts on nuclear physics are available, and these are recommended in preference to the present book for those engineers who are interested in a qualitative, semitechnical discussion of the field. But for those who are interested in a more-detailed, well-referenced, technical discussion, the present book can be recommended without further qualification.

For the Market Analyst, Engineer and Chemist

Starch—Its Sources, Production and Uses, Charles Andrew Brautlecht. Reinhold Publishing Corp., New York (1953), 393 pp. $10.00.

Reviewed by J. W. Opie, Head, Organic Development Sect., General Mills, Inc., Minneapolis, Minn.

It is difficult to cover thoroughly in 393 pages a topic as large as starch. The author of this book, as the title suggests, has therefore wisely limited his scope to the economic and industrial aspects of the field. An excellent chapter by Dr. Owen A. Moe on the physical and chemical characteristics of starch and its derivatives deviates from this policy, but will appeal to the more academic technologists.

A large proportion (127 pp.) of the subject matter is devoted to potatoes and potato starch, while corn starch receives only twenty-six pages. This emphasis on potato starch should attract many to this book, since the reviewer knows of no other treatise on this subject which is as complete.

Another lengthy section, devoted to the sweet potato, is quite welcome, since the literature of this product has not been previously assembled. Other starches receive shorter treatment.

Detailed economic data concerning each product are given, making the book valuable to the market analyst as well as to the engineer and the chemist.

Expanded descriptions of the manufacturing processes used for each starch are presented. These sections tend to be unnecessarily involved for the uninitiated and yet are too elementary for the engineer.

The author has failed to bring out the relative advantages of the different starches for various applications and has touched too lightly on the use of classical methods of modification.

Shoes and Ships and Sealing Wax . . .

Chemicals of Commerce, Foster Dee Snell and Cornelia T. Snell. D. Van Nostrand Co., Inc., New York, 2nd Ed. (1952), 587 pp., $6.50.

Reviewed by W. L. Faith, Corn Products Refining Co., Chemical Division, Argo, Ill.

The subject matter of this book covers all inorganic and organic chemicals worthy of the name "commercial" (25 chapters), as well as fats and oils, waxes, dyes, toners, lakes, colors, natural plant and animal products (e.g., nutmeg, corn silk, cuttlefish bone), extracts of natural products (e.g., quebracho extract and Irish moss), alkaloids, glucosides, essential oils, natural gums, synthetic and natural resins, elastomers, carbohydrates, proteins, vitamins, antibiotics, and hormones (13 chapters).

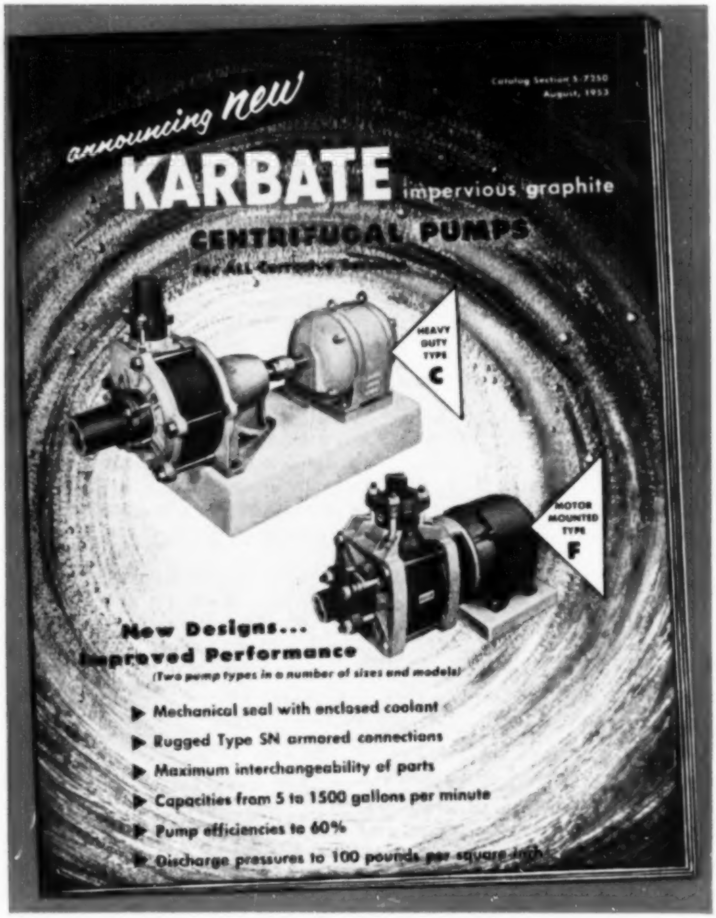
The treatment of each material varies roughly with its importance. Sodium hydroxide, one of the longer entries, takes up two pages. The discussion encompasses its appearance, solubility

(Continued on page 74)

NATIONAL CARBON OFFERS

MORE AND MORE FOR YOUR MONEY IN...

2 New "KARBATE" Centrifugal Pumps
BRAND



CATALOG SECTION S-7250 CONTAINS:

- Design improvements
- Materials and details of construction
- Standardization of parts
- Assembly information
- Model types, sizes, capacity ranges
- Dimensions
- Ordering information

WRITE FOR YOUR COPY NOW!

ALL "KARBATE" IMPERVIOUS GRAPHITE EQUIPMENT GIVES YOU:
BRAND

- OUTSTANDING CORROSION RESISTANCE
- COMPLETE IMMUNITY TO THERMAL SHOCK
- FREEDOM FROM METALLIC CONTAMINATION
- LONG LIFE—LOW MAINTENANCE

The term "Karbate" is a registered trade-mark of Union Carbide and Carbon Corporation

NATIONAL CARBON COMPANY
A Division of Union Carbide and Carbon Corporation
30 East 42nd Street, New York 17, N. Y.
District Sales Offices:
Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco
In Canada: National Carbon Limited, Montreal, Toronto, Winnipeg

The first tank car of high-boiling phenols recently was shipped from the coal-hydrogenation pilot plant of Carbide and Carbon Chemicals Co., Institute, W. Va. The company announced known components of 50% of the mixture as: indanol-4, approximately 15%; indanol-5, about 15%; 3-methyl 5-ethyl phenol, approximately 15%; n-propyl phenols (meta and para), 5 to 10%. This shipment will be used by a resin manufacturer. The mixture can also be used, the company states, in the manufacture of phenolic-lubricating additives, cresylic-type disinfectants, surface-active agents, and pharmaceuticals.

FOUNDATION SURVEYS URUGUAYAN INDUSTRIES

The Armour Research Foundation of Illinois Institute of Technology has signed a contract with the Republic of Uruguay to make a technological survey of the country's industries and resources. A three-man team will spend approximately six weeks in the field studying means to improve existing industries and possibly to establish new ones through the application of research and engineering technology. One of the aims of the investigation is the creation in Uruguay of an independent industrial research institute to serve the techno-economic needs of the country. Uruguayan capital is financing the project.

Similar technological "audits" have been conducted by the Foundation in other Latin American countries. The Mexican Institute of Technological Research is an outcome of such a project for Mexico several years ago.

NUCLEAR ENGINEERING TOPIC AT DINNER

The fifth annual dinner of The Chemical Profession in Cleveland will be held at the Hollenden Hotel in Cleveland on Wednesday, November 11.

Professor Harold C. Urey, of the Institute of Nuclear Studies, University of Chicago, will give a talk entitled "Cosmic Chemical Engineering."

The dinner is jointly sponsored by the Cleveland sections of A.I.Ch.E., A.C.S., Alpha Chi Sigma, American Institute of Chemists, and The Electrochemical Society.

FILM INFORMATION ISSUED BY A.I.Ch.E.

A booklet on films of interest to chemical engineers has been prepared by the Chemical Engineering Education Projects and Student Chapters committees of A.I.Ch.E.

The listing is divided into four parts: Part I notes under appropriate topics the films that the committee "believes to be pertinent to the general course content in the average Chemical Engineering Department." Part II covers films dealing with specific chemical industries. In both Parts I and II a brief description of the film, the length, the distributor, and the manner of distribution are noted. Part III is an alphabetical listing of film distributors. Part IV contains general film-information sources.

The booklet, entitled "Chemical Engineering Educational Films," is available without charge from the Office of the Secretary, A.I.Ch.E., 120 East 41st St., New York 17, N. Y.

THIS MONTH IN INDUSTRY

• American-Marietta reports acquisition of controlling interest in the Universal Concrete Pipe Co. of Columbus, Ohio.

• West Penn Power Co. announced the purchase of the distribution and transmission systems of Natrona Light and Power Co., a subsidiary of Pennsylvania Salt Mfg. Co. Pennsalt will retain its facilities inside its Natrona Plant for its chemical manufacturing processes.

• Purchase of the Chemical Porcelain Division of the Illinois Electric Porcelain Co. of Macomb, Ill., was announced by U. S. Stoneware Co. of Akron, Ohio.

• Modification of its contract with the Atomic Energy Commission will give Union Carbide and Carbon Corp. responsibility for the operation of additional facilities at Oak Ridge, Tenn., and Paducah, Ky. The term of the contract has been extended to June 30, 1957.

• Vanton Pump & Equipment Corp. is the new name of Vanton Pump Corp., New York, which has added valves, pipe, and fittings to its products.

• W. R. Grace & Co. has purchased for partial occupancy the Cotton Exchange Building on Hanover Square, New York. Subsidiary companies will be moved into the new quarters, which face the company headquarters.

• Owens-Illinois Glass Co., Toledo, has invested $8,000,000 in Plax Corp., West Hartford, Conn., manufacturers of plastic sheet, tubing, containers, etc.

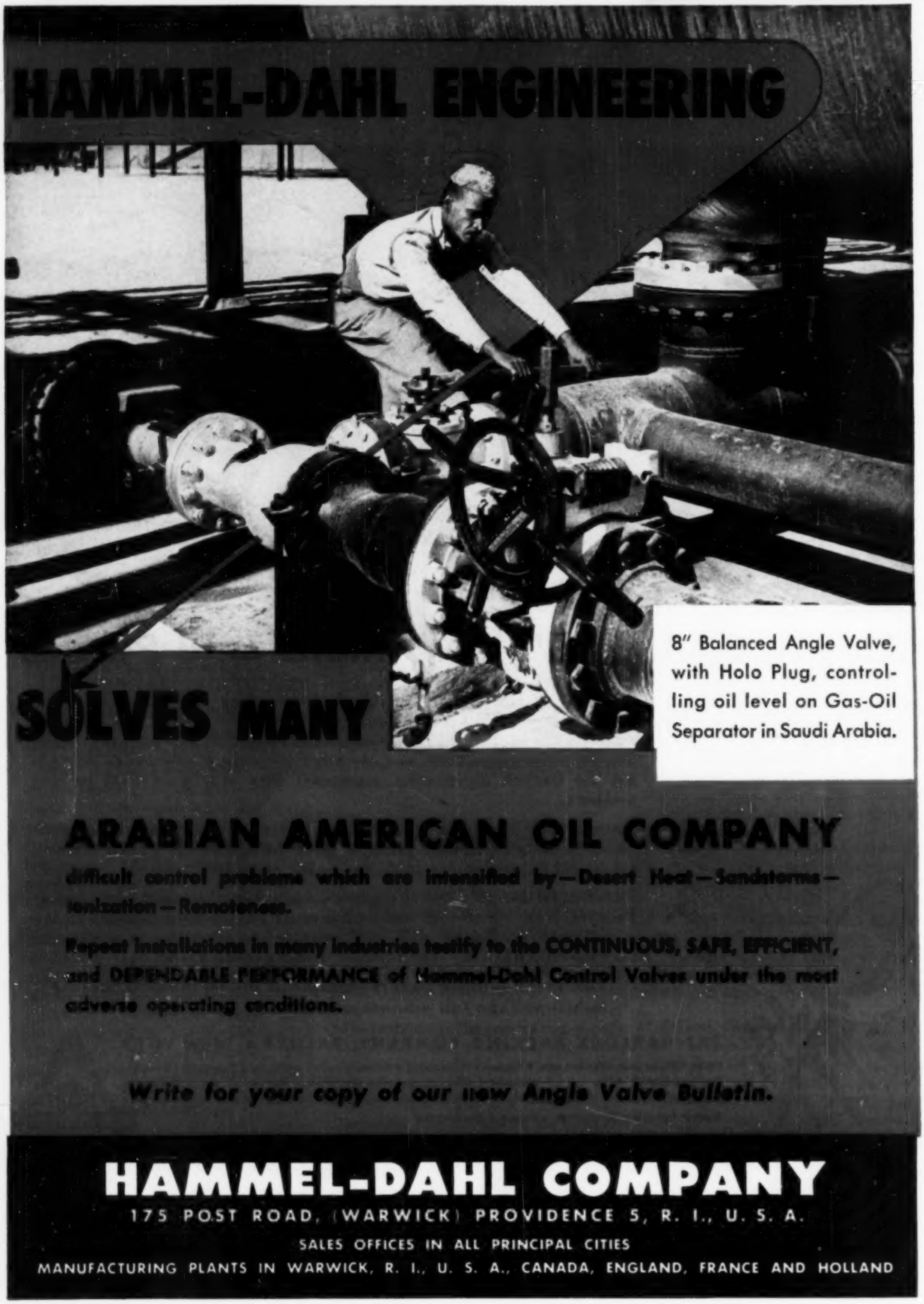
• Arthur D. Little, Inc., Cambridge, Mass., will open a new Midwest liaison office in Chicago, Ill.

• Davis & Geck, Inc., a unit of American Cyanamid, announced the start of a year-long move of its manufacturing facilities from Brooklyn, N. Y., to Stamford, Conn.

• Dow Chemical International, Ltd., has announced the establishment of a plant for the manufacture of saran monomer and polymer plastics at Nobeoka on Kyushu Island, Japan. The new plant is jointly owned by Dow and Asahi Chemical Industry Co., Ltd.

• The Plaskon Division of Libbey-Owens-Ford Glass Co. has been purchased by Allied Chemical & Dye Corp. and will be operated as part of its Barrett Division.

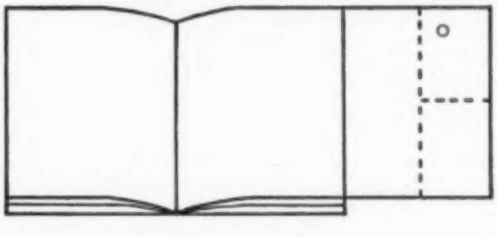
(*News continued on page* 46)


HAMMEL-DAHL ENGINEERING
SOLVES MANY
8" Balanced Angle Valve, with Holo Plug, controlling oil level on Gas-Oil Separator in Saudi Arabia.
ARABIAN AMERICAN OIL COMPANY
difficult control problems which are intensified by—Desert Heat—Sandstorms—Ionization—Remoteness.
Repeat installations in many industries testify to the CONTINUOUS, SAFE, EFFICIENT, and DEPENDABLE PERFORMANCE of Hammel-Dahl Control Valves under the most adverse operating conditions.
Write for your copy of our new Angle Valve Bulletin.
HAMMEL-DAHL COMPANY
175 POST ROAD, (WARWICK) PROVIDENCE 5, R. I., U. S. A.
SALES OFFICES IN ALL PRINCIPAL CITIES
MANUFACTURING PLANTS IN WARWICK, R. I., U. S. A., CANADA, ENGLAND, FRANCE AND HOLLAND

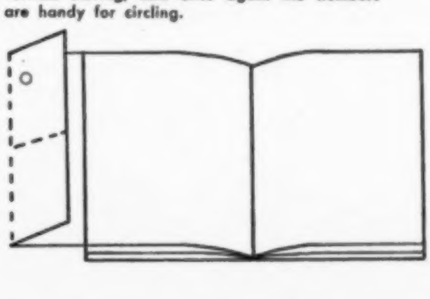
for your information

This "C.E.P." information service is a convenient way to get the chemical engineering information you need on new equipment, on advertised products, on the newly announced developments reported on these pages. A one post card inquiry designed to bring data quickly and easily. Circle the items of interest, sign your name, position, address, etc., and drop in the mail.

Just a moment is needed to learn how to use this insert. When looking through the front part of the magazine pull the folded portion of the insert out to the right, and the numbers on the post card are convenient for marking. THEN . . . .



as you pass the pull-out page, and, it is on the left, fold the post card back along the vertical scoring, and once again the numbers are handy for circling.



Postage Will Be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

First Class Permit No. 48690, Sec. 34.9, P. L. & R., New York, N. Y.

CHEMICAL ENGINEERING PROGRESS
120 East 41st Street
New York 17,
New York

Postage Will Be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

First Class Permit No. 48690, Sec. 34.9, P. L. & R., New York, N. Y.

CHEMICAL ENGINEERING PROGRESS
120 East 41st Street
New York 17,
New York

PRODUCTS

IFC **Louisville Cooler**
Surface coolers, water tube coolers, and atmospheric coolers.
Louisville Drying Machinery Unit, General American Transportation Corp.

3R **Instrumentation for Variables**
For the measurement and control of variables.
Fischer & Porter Co.

4L **Standardaire Blowers**
Helically-shaped rotors compress air.
Read Standard Corp.

5A **Continuous Centrifugal**
7 different pool depths, variable beach speeds from 0 to 300 in. per minute, 2000 F x G, and self-cleaning feed chambers.
Tolhurst Centrifugals Div., American Machine and Metals, Inc.

6L **Filtration**
Large volume filters in sizes from 100 sq. ft. to 2000 sq. ft. of filtering surface. Horizontal plate filters for fine filtration also.
Sparkler Manufacturing Co.

7A **Chemical Service Valves**
Durco Type B valves for sulfuric acid service. Bulletin V/2.
The Duriron Co., Inc.

8A **Wedge Gate Valves**
Alloy trimmed, alloy cast iron gate valves. Circular No. 14477.
Crane Co.

9A **Heat Transfer Medium**
For chemical, petroleum, paint, food and other process industries.
The Dow Chemical Co.

10A **Thermometer Controller**
23 different temperature ranges. Bulletin 6401.
Minneapolis-Honeywell Regulator Co.

12L **Mixing and Blending**
Tilting and stationary bowl models, capacities one quart to 1500 gallons. Bulletin 53759.
Read Standard Corp.

13A **Stainless Piping**
All standard pipe size schedules in a complete range of stainless steel grades.
The Babcock & Wilcox Co., Tubular Products Div.

14A **Pressure Filter**
Style "H" Filter will filter liquids at rates up to 30,000 gal./hr.
Niagara Filters Div., American Machine and Metals, Inc.

15A **Process Plants**
Designing, engineering, and building plant construction or modernization.
The Girdler Co.

16A **Continuous Dilution**
For paper production. Also proportioning, sampling, blending, diluting, and feeding. Bulletin 1400.
Proportioneers, Inc.

512A **Tygon Gaskets**
Also tubing, tank lining, and paint.
U. S. Stoneware Co.

19A **Gasholder**
Modern sewage digester gasholder illustrated.
Wiggins Gasholder Div., General American Transportation Corp.

21A **Seal-less Pumps**
Available in 1/3, 3/4, 1, 2, and 3 horsepower sizes.
Chempump Corp.

23A **Buflovak Kettles**
For heating, cooling, mixing, extracting, reacting, distilling, evaporating, drying, and solvent recovery. Free color booklet.
Blaw-Knox Company, Buflovak Equipment Div.

24L **Heat-Transfer Engineering**
Services and units.
Aerofin Corp.

25A **Pulsafeeder Double-Diaphragm Pumps**
Controlled-volume pumping. Bulletin 300.
Lapp Insulator Co.

26L **Yorkmesh Demister**
For mist separation in a vacuum tower.
Otto H. York Co., Inc.

27A **Fluor Engineering and Construction**
Design, erection and initial operation of plants and facilities for the oil, gasoline, chemical, power and allied industries.
The Fluor Corp., Ltd.

29A **Petroleum Caustic Soda for Refining**
Graphite anodes, electrodes, molds and specialties.
Great Lakes Carbon Corp., Electrode Div.

31A **"Karbate" Centrifugal Pumps**
Impervious graphite equipment. Catalog Section S-7250.
National Carbon Co.

33A **Mechanical Packing**
Manufacture, application and development of mechanical packings.
The Garlock Packing Co.

34A **Gas-Oil Separator Valves**
Control valves. Angle valve bulletin.
Hammel-Dahl Co.

43A **Process Filtration**
Continuous vacuum and pressure filters.
The Eimco Corp.

45A **Conkey Evaporators**
Periodic switching permits all fouled surfaces to be washed free. Write for details.
Process Equipment Div., General American Transportation Corp.

46L **"Standard"-ized Drying**
30 types of Standard-Hersey dryers. Bulletin No. 531.
Standard Steel Corp.

47A **Pyrex Glass Processing Equipment**
Glass No. 7740 for coolers, condensers, fractionating columns, piping and other processing equipment. Bulletin, Data Sheets.
Corning Glass Works

48L **Metallic Filter Cloth**
Available in a variety of weaves in all malleable metals. Catalog E.
Newark Wire Cloth Co.

Chemical Engineering Progress

Numbers followed by letters indicate advertisements, the number corresponding to the page carrying the ad. This is for ease in making an inquiry as you read the advertisements. Letters indicate position—L, left; R, right; T, top; B, bottom; BR, bottom right; TR, top right; A indicates a full page; IFC, IBC, and OBC are cover advertisements.

Be sure to give name, address, position, etc.

Remember, the numbers on the upper portion of the card bring you data on only the bulletins, equipment, services, and chemicals reported in these information insert pages. The lower portion of the card is for the advertised products, and is keyed not only to advertising pages, but also to the memory-tickling list under the heading Products.

49A **Insulation Engineering Service**
Materials and application.
Johns-Manville

50A **Anodes**
Controlled density, uniform structure, high purity and mechanical strength.
Speer Carbon Co.

51A **Nordstrom Valves**
Valves and valve lubricants.
Rockwell Manufacturing Co.

53A **Drying Problems**
Drying research laboratory.
C. G. Sargent's Sons Corp.

55A **Sectional Heat Exchangers**
Fintube heat exchangers of standard sections connected in series and parallel arrangement. Bulletin 512.
Brown Fintube Co.

58L **Tantalum**
Used for most acid solutions and corrosive gases or vapors except HF, alkalis, or substances containing free SO_3. Free booklet.
Fansteel Metallurgical Corp.

59A **Desliming or Degritting**
Two 12 in. dia. DorrClones degrit high silicon content clay.
The Dorr Co.

60L **Knight-Ware Chemical Stoneware**
Resistant to acids and alkalies. Bulletin No. 12-F.
Maurice A. Knight

(Continued on back of this insert)

Please do not use this card after March, 1954

1	2	3	4	5	6	7	8	9	10	11	12	14	15
16	17	18	20	21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40	41	42	43	44
45	46	47	48	49	50	51	52	53	54	55	56	57	58
59	60	61	62	63	71	72	73	74	75	76	77	78	79
80	81	82	83	84	85	86	87	88	89	90	91	92	93
94	95	96	97	98	99	100	101	102	103	104	105	106	107
108	109	110	111	112	113	114	115	116	125	126	127	128	129
130	131	132											

Advertisers' Products

IFC	3R	4L	5A	6L	7A	8A	9A	10A
12L	13A	14A	15A	16A	512A	19A	21A	23A
24L	25A	26L	27A	29A	31A	33A	34A	43A
45A	46L	47A	48L	49A	50A	51A	53A	55A
58L	59A	60L	61A	62L	63A	64L	64R	65A
66L	66R	67A	69R	70L	71R	72L	72R	73R
75T	75B	76T	76B	77R	78L	78TR	78BR	79T
79B	81R	82T	82B	83TR	83BR	IBC	OBC	

Chemical Engineering Progress Data Service

Name ....

Position ....

Company ....

Address ....

City ....Zone .....State ....

☐ I want a subscription. Bill me $6.00 for a year.

October, 1953

Please do not use this card after March, 1954

1	2	3	4	5	6	7	8	9	10	11	12	14	15
16	17	18	20	21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40	41	42	43	44
45	46	47	48	49	50	51	52	53	54	55	56	57	58
59	60	61	62	63	71	72	73	74	75	76	77	78	79
80	81	82	83	84	85	86	87	88	89	90	91	92	93
94	95	96	97	98	99	100	101	102	103	104	105	106	107
108	109	110	111	112	113	114	115	116	125	126	127	128	129
130	131	132											

Advertisers' Products

IFC	3R	4L	5A	6L	7A	8A	9A	10A
12L	13A	14A	15A	16A	512A	19A	21A	23A
24L	25A	26L	27A	29A	31A	33A	34A	43A
45A	46L	47A	48L	49A	50A	51A	53A	55A
58L	59A	60L	61A	62L	63A	64L	64R	65A
66L	66R	67A	69R	70L	71R	72L	72R	73R
75T	75B	76T	76B	77R	78L	78TR	78BR	79T
79B	81R	82T	82B	83TR	83BR	IBC	OBC	

Chemical Engineering Progress Data Service

Name ....

Position ....

Company ....

Address ....

City ....Zone .....State ....

☐ I want a subscription. Bill me $6.00 for a year.

October, 1953

PRODUCTS *(Continued)*

61A **I-R Steam-Jet Ejectors**
Available in single-stage, two-stage, and multiple-stage designs. Bulletin 9013A.
Ingersoll-Rand

62L **Stainless Steel Fittings**
Assemble and disassemble with an Allen wrench. Manual Q100.
The Cooper Alloy Foundry Co.

63A **Teflon Diaphragms**
Valves available with a wide choice of manual, remote and automatic operators.
Hills-McCanna Co.

64L **Polyethylene Pumps**
For corrosive and hazardous fluids. Capacities from fractional to 20 gpm. Booklet.
Vanton Pump and Equipment Corp.

64R **Actinic Radiation for Photochemistry**
Photochemical equipment for continuous flow, batch or recycling processes. Literature.
Hanovia Chemical & Mfg. Co.

65A **Brazed Aluminum Heat Exchangers**
Extended surface heat transfer equipment. Free book.
The Trane Co.

66L **Antifoam**
Defoamers for the processing industry. Coupon for free sample.
Dow Corning Corp.

66R **Paracoil Heat Exchangers**
Special equipment, pilot plant units or plant modernization programs.
Davis Engineering Corp.

67A **Celite Diatomite Powders**
Absorb twice their own weight of liquid.
Johns-Manville

69R **Controlled Humidity Air Conditioning**
Removes the excess moisture from out-door air by contact with an absorbent liquid in a spray chamber. Write for information.
Niagara Blower Co.

70L **24th Exposition of Chemical Industries**
Philadelphia, Nov. 30 to Dec. 5.
Chemical Industries Exposition

71R **Electronic Tank Gauge Receiver**
For 36-foot range tanks and smaller. No. 8800 series. Coupon for Bulletin CP-3004.
The Vapor Recovery Systems Co.

72L **Vitreosil Crucibles, Dishes, Trays**
Immune to extreme chemical, thermal and electrical conditions. Bulletin No. 17.
The Thermal Syndicate Ltd.

72R **Constant-Weight Feeder**
Regulating feeder. Bulletin 33-D-40. Electronic mill feed control. Bulletin 42-40.
Hardinge Co., Inc.

73R **Process Equipment**
Engineering and manufacturing.
Badger Manufacturing Co.

75T **Special Filtering Problems**
Packaged plant for continuous filtration of molten phosphorus. Also standard filtering problems. Bulletin No. 431.
R. P. Adams Co., Inc.

75B **Spraco Nozzles**
Full cone, flat spray, and hollow cone. Catalog.
Spray Engineering Co.

76T **Filter Presses**
For practically any kind of filter material. Catalog.
D. R. Sperry & Co.

76B **Bubble Caps**
Bulletin 21 lists 200 styles. Special caps designed.
The Pressed Steel Co.

77R **Technical Molybdenum Trioxide**
The raw material for the production of all molybdenum compounds.
Climax Molybdenum Co.

78L **Color Comparators**
For phosphate, pH, chlorine determinations. 96 page book.
W. A. Taylor and Co.

78TR **Pipe-Cutting Pantograph**
Guided torch machine for all types of pipe cuts. Bulletin P-2.
Vernon Tool Co., Ltd.

78BR **Synchro-Lectric Viscometer**
Adaptable to any problem for less than one to 32,000,000 centipoises. Catalog.
Brookfield Engineering Laboratories, Inc.

79T **Steam Traps**
For heat, power, process; sizes ¼ in. to 2 in.; pressures to 250 lbs. Bulletin 853.
W. H. Nicholson & Co.

79B **Furane Resin Cement**
Mortar for corrosion-resistant masonry, supplied in the form of powder and liquid, for mixing at time of use. Folder.
Delrac Corp.

81R **Pumps and Compressors**
Check valves, compressors, and centrifugal pumps. Catalog 546.
Pennsylvania Pump & Compressor Co.

82T **Industrial Balances**
Micrometer-poise balance for speedy determination of weight.
Ohaus Scale Corp.

82B **Agitator Drives**
Double and triple reduction drive unit.
Western Gear Works

83TR **Plate Fabrication**
Towers, pressure vessels and heat exchangers a specialty.
Downingtown Iron Works, Inc.

83BR **C-R Chill-Vactor**
Steam-jet vacuum unit to flash-cool water and other liquids down to 32° F.
Croll-Reynolds Co., Inc.

IBC **Chemical Plant Construction**
Construction, renovation, erection and installation in the field.
The Vulcan Copper & Supply Co.

OBC **Lightnin' Mixers**
Sizes from ⅛ to 500 h.p. Catalogs.
Mixing Equipment Co., Inc.

EQUIPMENT

1 **Pole Motors.** Developed by Burgess Vibrocrafters, Inc. 1/50 to 1/8 hp. two-pole shaded pole motors, half the size and weight of normal motors of same rating.

2 **Line Burner.** Manufactured by Eclipse Fuel Engineering Co. gas-fired retention-type line burner. Use where heat is distributed over wide area by continuous flame. Recommended for oven, kettle, air heating.

3 **Systems Control.** Foxboro Co. control for consistency and acid concentration of slurry systems. Application engineering data sheet contains much pertinent information. Originated for use in production of titanium-based pigments but now available for control of other difficult processes where slurries are involved.

4 **Pressure Switch.** Capable of sensing pressure over adjustable range 15, to 3,000 lb./sq. in. and actuating circuit on increase or decrease of pressure, heavy-duty pressure switch from Barksdale Valves.

5 **Fatty Acid Distillation.** From General Industrial Development Corp. multicolored folder on Wecker plants for distillation of fatty acids and for deacidifying oils. Discuss operation, features, apparatus, etc.

6 **Size Distribution Analyzer.** For quick determination of particle-size distribution, an analyzer from Sharples Corp. Research Labs. Named micromerograph. For producers of cements, pigments, metal powders, drugs, chemicals.

7 **Specific Gravity Meter.** A standardized, packaged instrument for continuous measurement of specific gravity introduced by Ohmart Corp. Uses radioactivity for measuring liquids, slurries, sludges, or granular materials. Accuracy $\pm$.005 in any range. Eight standard ranges.

8 **Plastic Pumps.** Cooper Alloy Foundry Co. and Vanton Pump Corp. plastic pumps, valves, and fittings. Eliminate danger of metallic contamination; wide corrosion resistance required in chemical process industries.

9 **Flowmeter.** Taylor Instrument Companies development for measuring liquid, steam or gas flow; liquid level or specific gravity. Illustrated, detailed leaflet includes cutaway views.

10 **Pressure Regulators.** Fischer & Porter Co. constant pressure differential regulator and an instrument air-pressure regulator. Catalog carries complete details, schematic drawings, other data.

11 **Immersion Heater.** Added to Chromalox electric heating units a flanged tubular type. Supplements present units for heating water, oil, or paraffin. Available in 120 to 550 v. ratings; capacities 4 to 12 kw. E. L. Wiegand Co.

12 **Safety Mask.** Cyclo-Flo Co. safety mask, 30 min. breathing apparatus called Poketaire. Weighs 8½ lb., features 5 min. escape cylinder for opening when large cylinder is exhausted.

14 **Stainless Steel Pump.** For drug and chemical industries, stainless steel pump, self-priming. Eliminates check valves, stuffing boxes, etc. Capacities 1/3 to 20 gal./min.; discharge pressure 0 to 60 lb./sq.in. gauge; suction lifts to 26 in. Vanton Pump Corp.

15 **Filters.** Redesigned line of Titeflex, Inc., filters. Less floor space, control valve motor and pump relocation. Use backwash to clean.

16 **Water Conditioning.** Elgin Softener Corp. bulletin on water conditioning. Sections on softeners, zeolites, ion-exchange resins, deionizers, water-treating chemicals, etc.

17 **Filter Aid.** A new carbonaceous filter aid, insoluble in caustic solutions from Anthracite Equipment Corp. AnthraAid exhibits chemical and physical properties advantageous in industry. Samples of four grades available.

18 **Filter Medium.** New filter medium, Kel-F., announced by Porous Plastic Filter Co. Resistant to strong acids, caustics, oxidizing agents and organic solvents. For use at temperatures to 300° F.; tensile strength 900 lb./sq.in.

20 **Flexi-Speed Drive.** New to Reeves Pulley Co., flexi-speed—a variable speed drive. Speed ratio up to 8:1. Used with right angle or parallel shaft reducers, ½- to 1-hp. capacities.

21 **Lubricators.** High-pressure, force-feed lubricators for service to 30,000 lb. from Manzel Division Frontier Industries, Inc. Used in chemical field for cylinder and bearing lubrication of compressors.

22 **Portable Hot Plate.** Inexpensive portable hot plate for small volume work (750° F. in 35 min.) Lindberg Engineering Co.

23 **Automatic Control System.** For gravimetric proportioning, blending and batching. Automatic control systems by CDC Control Services, Inc. Weight accuracy 0.015% at speeds of 0.01 sec.

24 **Synthetic Filter Fabrics.** Filtration Fabrics Division of Filtration Engineers, Inc., announces new method of cutting holes, straight or curved edges, etc., and sealing edges on synthetic fabrics by electrically heated blades. Tightly bonded edge prevents raveling.

25 **Ladder Tread.** A newly designed formed metal tread increasing safe footing added to Ballymore Co. safety ladders.

26 **Hydraulic Foam Tower.** Portable foam tower, raised and lowered by hydraulic action offered by National Foam Systems, Inc. Used in fighting flammable liquid tank fires. Quickly erected, used for tanks of varying heights. Simple conversion adapts for chemical foam use.

27 **Controller.** Contact-type, Cyber-Tac, controller for use with electronic circuit. Combination cut-off and automatic hold type with thermocouple break protection. Control to 2% of full-scale range. Cybertronic Corp. of America.

28 **Tel-Flo Meter.** Tel-Flo meter from Uehling Instrument Co. for measuring flow rates and purging line. For maximum pressures of 300 lb. Higher upon request.

29 **Conveyors.** Armorbelt conveyors announced by M-H Standard Co. Belt runs on protected ball bearings. Inclined or vertical models.

30 **Flow Detector.** From Fenwal Inc., precision flow detecting instrument which may be used as warning device in air-cooled equipment, ventilation control or similar application. Also as liquid-level detector or controller in storage and supply tanks.

31 **Hose Safety.** "Dangers Under Pressure," a new safety booklet available from Hose Accessories Co.

32 **Regulating Valve.** Regulating valve from Natural Gas Equipment, Inc. The Thomas Magna-Stroke available in all types. Works at ratio of 2:1 giving twice the stroke at inner valve as to diaphragm.

33 **Proportioning Pumps.** For the chemical, textile, petroleum, etc., industries, proportioning pumps from Walter H. Eagan Co., Inc. Meter quantities from 0 to 100 gal./hr. at pressures of 1200 lb./sq.in. Special units of 300 gal./hr. pressures to 20,000 lb./sq.in.

34 **Shuttle Valves.** To provide automatic switchover from either of two control stations, shuttle valves from James-Pond-Clark. Shuttling action with tight sealing at pressure differentials of less than 1/3 lb./sq.in. to 3000 lb./sq.in.

35 **Condenser Tube Kit.** New cleaning and application kit to remove deposits from condenser tubes, from Thos. C. Wilson, Inc.

36 **Controlled Mixing Equipment.** Added to line of National Engineering Co. is Simpson LF Mix-Muller for industrial laboratories. Designed for ceramic, chemical, and process industries. Bulletin gives outstanding features.

37 **Portable Analysis Unit.** Self-contained portable unit for use in microanalysis. Can perform all basic operations of ultramicro analysis in acidimetry and oxidimetry titrations, filtrations, etc. Cabinet 2 ft. high, 3 ft. wide, 18 in. deep. Built-in electrical connections. Microchemical Specialties Co.

38 **Portable Indicating Instruments.** Two series of portable electric instruments announced by General Electric Co. Available to indicate volts, watts, amps, and milliamps.

39 **Steam Valves.** Atkomatic Valve Co. stick-free steam valves. Design compensates for both expansion and deposits.

40 **Rotary Vacuum Pump.** Vacuum pump added to line of Lammert & Mann Co. Rotary principle, no valves or reciprocating parts. Need not be fastened to floor. No tanks or receivers necessary except for special systems. Sizes 1 to 5½ with capacities 4.3 to 84 cu.ft./min. free air.

41 **Filter Felt.** Introduced by American Felt Co., a filter bonded Dynel felt. For use in filter press or vacuum filter applications.

42 **Lift Truck Scale.** For any hydraulic cylinder-type-lift truck the Martin-Decker Corp. lift-truck scale. Capacity 2,000 to 20,000 lb. Permits floor weight distribution, eliminates accidents from overload. Illustrated bulletin.

43 **Canal Liner.** Johns-Manville asbestos prefab canal liner for protection against water seepage from irrigation systems, stock ponds, reservoirs. Also as liner for industrial retention ponds holding waste materials. Rolls are 36 in. wide, 108 sq.ft./roll. Material is asbestos felt saturated and coated with special asphalt.

44 **Chemical Resistance Tables.** Binder inserts giving tables of chemical resistance of various types of rubber, available from Lee Tire & Rubber Co. Cover commercial organic, organic chemicals, acids, salts, and miscellaneous.

45 **Valves.** Corrosion-resistant plastic globe and Y valves. Polyethylene except for sealing diaphragm on disc. Withstand most acids, caustic solutions. Pressure to 50 lb./sq.in., temperatures to 150° F. Now available in ½ to 2 in. sizes. Vanton Pump Corp.

46 **Stainless Alloy.** Cooper Alloy Foundry Co. New 18-8 type hardenable stainless alloy. High hardness. Nongalling, good corrosion resistance.

47 **Chromatographic Separation.** Chromo Pup announced by Enley Products, Inc., for chromatographic separation of rare earths, sugars, antibiotics, etc. Constructed of acrylic resin permits progress observation.

48 **Stress Rupture Data.** From Babcock & Wilcox Co., binder insert technical data card on stress rupture data on B & W Croloys. For evaluation of characteristics of metals under stress.

49 **Rubber Conveyor Belting.** Rubber Conveyor belting with rubber cleats forming an integral part of the belt, announced by Goodall Rubber Co. For bulk handling of foods, chemicals, pharmaceuticals, coal, etc.

50 **Back-up Rings.** Garlock Packing Co. spirally machined Teflon back-up rings designed to prevent extrusion of O rings. High impact strength from —100° F. to +500° F. Noncorrosive, nonfraying, self-lubricating.

51 **Mercury Recovery.** Acme Protection Equipment Co. announces Mer-Vac method of recovering mercury globules and mercury-laden dusts. Combats hazard of mercury vapor poisoning. Combination gas mask canister for vapor collection; industrial vacuum cleaner for mercury recovery.

52 **Silicone Rubber Parts.** General Electric Co. announces new silicone rubber for production of uniform parts from ordinary rubber molds. Recommended for capacitor bushings, O-rings, packings in engines.

53 **Laboratory Scale.** Laboratory and research scale from Exact Weight Scale Co.

54 **Flow Meter.** Linameter, a Penn Industrial Instrument Corp. variable-area-type flowmeter now available with pneumatic transmission. All metal, mounted directly in the pipe line. Measures rate from 0.3 to 3 gal./min. Sizes 2 to 8 in.

55 **Test Chambers.** New line of multirange, all-purpose test chambers for producing temperature to —130° F. to 200° F., humidity cycle 20% to 95% from +35° F. to +185° F., introduced by Murphy & Miller, Inc. Five sizes; test space capacity 4 to 36 cu.ft.

56 **Sludge Controller.** From Simplex Valve & Metal Co. a sludge controller with electrical transmission. Designed to control flow of sludge or heavy liquids, 8 in. diam. Affords complete cutoff or maximum flow conditions.

57 **Teflon Sheets.** Available from Ethylene Chemical Corp., low porosity, high density, high tensile, Teflon sheets. Also stress-relieved sheets. Size 29 x 29 in.; thickness .050 in. to 2 in.

58 **Hammer Mill.** Schutte Pulverizer Co. hammer mill with quick screen-change feature. Screen withdrawn and replaced without stopping mill. Sizes 20 to 125 hp. either belt-driven or direct-connected models.

59 **Valves.** Designed for industrial applications where ammonia and gases noncorrosive to steel are used. Catalog covers valves and fittings. Henry Valve Co.

60 **Riveted Roller Chain.** Improved assembly riveted roller chain announced by Chain Belt Co. Bulletin contains section on how chain is made to any length. Strengths, dimensions, weights or standard chain.

61 **Viscometer.** Norcross Corp. line of viscometers, an indicating instrument for applications not requiring a permanent record. Dial 6-in., either panel or wall mounting.

62 **Pipe Insulation.** A one-piece, molded, fine-glass-fiber pipe insulation from Gustin-Bacon Mfg. Co. Features are light weight, thermal efficiency, resilience, insolubility in water, nonbreakable. For applications up to 350° F. Bulletin.

63 **Continuous Centrifugal.** Introduced by Tolhurst Centrifugals Division of American Machine and Metals, Inc., continuous centrifugal. Either short runs on different products or long runs on single product. Drive permits instantaneous speed changes from 0 to 300 in./min. Seven pool depths available by simple adjustment. Available for 90-day tests.

CHEMICALS

71 **Extruded Thermoplastics.** Plax Corp. brochure on extruded thermoplastics. Table compares polyethylene, methacrylate, polystyrene and fluorocarbons. Second section shows forms in which plastics are available, dimensions, surface, color, uses and applications.

72 **Teflon.** From Ethylene Chemical Corp. bulletin on Teflon. Available are round tubing, molded tubes, rod, and tape. Tables of properties, dimensions. Characteristics listed, flow sheets, etc.

73 **Polyvinyl Resin.** Bulletin on Colton Chemical Co. Vinac polyvinyl acetate solid resin. Uses, applications, and properties of Vinac beads. Regular solvent or alkaline soluble types. For use in adhesive, paper, textile industries. Other Colton products also listed.

74 **Water Repellent Finish.** DeCetex 104 from Dow Corning Corp. Water-dilutable emulsion for synthetics and synthetic blends. Fabrics treated retain high spray ratings after cleaning. Colorless. No afterwash or neutralizing.

75 **Liquid Linings and Coatings.** Folder from Gates Engineering Co. describes chemical and abrasion-resistant tank linings and coatings. Quick drying, easily applied. Variety of colors.

76 **o-Phenylphenol.** o-Phenylphenol in white flake form essentially colorless, odorless, from Dow Chemical Co. Industrial preservative. Bulletin.

77 **Butyrate Lacquer.** Eastman Chemical Products, Inc. booklet on half-second butyrate lacquer. Data on compatability with 125 natural and synthetic resins, oils, waxes. Data on hardness, tensile strength, flexibility, water immersion, formulation suggestions, etc.

78 **Anhydrous Ammonia.** "Guide to the Use of Anhydrous Ammonia," from Allied Chemical & Dye Corp. Gives specifications in cylinders, covers applications, handling and operating techniques, safety instructions, charts, technical drawings.

79 **Resorcinol.** Use of Resorcinol as an intermediate in pharmaceutical and industrial production. Koppers Co., Inc. Historical background, use in low-temperature bonding of plastics, textile dyes, etc.

80 **Aldehydes.** Describing aldehydes, a 36-page book from Carbide and Carbon Chemicals Co. Detailed are fourteen aldehydes available commercially. Others in research quantities. Uses and applications, properties, test methods, constant-boiling mixtures listed.

81 **Polystyrene Emulsions.** From Koppers Co., Inc., technical bulletin. Properties and characteristics of four polystyrene emulsions, stable water dispersions of high molecular weight. Uses and applications in reinforced plastics, water-base coatings, primers and sealers discussed. Tables of compatible organic and inorganic pigments.

82 **Liquid Polymer-Epoxy Resin.** Combinations from elastomers to hard resins prepared by co-curing Thiokol Chemical Corp. liquid polymers with liquid epoxy resins. Process at room temperature. For use as sealants, coatings, adhesives. Portfolio on subject.

83
84 **Aluminum.** (83) Aluminum Co. of America booklet on aluminum in process industries. Illustrated, discusses economic advantages, lists mechanical properties, solution potentials. (84) Folder on Alcoa chemicals—aluminas and fluorides.

85 **White Liquor Polishing.** Dorr Co. white liquor polishing station of one or more polishing filters, vertical pressure type with piping, valves, and control instruments. Produces clear cooking liquor for pulp producers by removing colloidal impurities too fine for econmical gravity settling.

86 **Water Detection.** Announced by R. P. Cargille Labs., Inc. Mois-Tec reagent for traces of water. Applicable to anhydrous solvents, paint thinners, cleaning solvents, oils, greases, etc.

87 **Sodium Perborate.** Available in quantity from Buffalo Electro-Chemical Co. sodium perborate. Contains 10% active oxygen by weight. For use in textile industry, in powder bleaches, cosmetics, etc.

88 **Formaldehyde.** Bulletin on UF concentrate 85 a high-concentrated liquid formaldehyde from Allied Chemical & Dye Corp. Analysis, physical properties, advantages, other pertinent data.

89 **Gelling Agent.** Permagel for aqueous or organic systems, gelling agent from Attapulgus Minerals & Chemicals Corp. Material is inorganic purified colloidal form of mineral attapulgite. Used in lubricating greases, cosmetics, rubber, paint, insecticides.

BULLETINS

90 **Grinding and Mixing Equipment.** Detailed bulletin from U. S. Stoneware Co. gives technical data on standard line of grinders and mixers. Also on new Roalox-burundum-fortified mill jars of wear-resistant, high-fired burundum-like body. Data, photographs, etc.

91 **Steam Traps.** Book on Armstrong Machine Works steam traps. Lists and describes line. Selection and application data for most condensate drainage problems.

92 **Gear Pumps.** From Schutte and Koerting Co. A 2-color bulletin lists standard- and special-type-gear pumps. Covers design, construction, and operation, how used in petroleum, petrochemical, food, textile, and other industries. Handles material viscosity ranges 30 to 10,000,000 S.S.U.

93 **Feeders.** To control withdrawal rate of materials from bins to hoppers and their discharge to conveyors or subsequent processing equipment. Catalog from Hardinge Co., Inc. on constant-weight, weight-measuring, volumetric belt, and disc feeders.

94 **Flame Cutter.** Vernon Tool Co., Ltd. flame cutter. Variable-speed transmission unit assures control of cutting speed.

95 **Lighting Fixtures.** Redesigned explosion-proof lighting fixtures from Crouse-Hinds Co. Shows cutaway view, describes components, performance data, methods of installing.

96 **Plastic Pipe and Tubing.** Extruded rigid polyvinyl chloride plastic pipe and tubing in wide-size range and full range of fittings in new, unplasticized polyvinyl chloride from Alpha Plastics, Inc. Water absorption 0.2% in 24 hr. at 25° C. Heat distortion only above 165° F.

97 **Laboratory Furniture.** Loose-leaf catalog from Metalab Equipment Corp. Sections on tables, sectional units, special equipment, desk, chairs. Illustrated.

98 **Corrosion Resistance.** American Brass Co. study on "Corrosion Resistance of Copper and Copper Alloys." Gives results of laboratory and field studies. Stress-corrosion cracking, galvanic corrosion, fresh and salt water corrosion, corrosion in petroleum refineries.

99 **Gates and Valves.** Stephens-Adamson Mfg. Co. bulletin on gates and valves, including Twistite double-closure bin valve and Moore bin gate.

100 **Pressure Pipe Fabrication.** Brochure from Lummus Co. details fabrication of pressure piping. Production steps, shop facilities, etc., pictured. Demonstrates bending of large-diameter, heavy-wall pipe.

101 **Power Transmission and Conveying Equipment.** Chain Belt Co. catalog on cast and steel chain, cast tooth sprockets, belt conveyor idlers, etc. Corrosion- and abrasion-resistant Rex Z-metal.

102 **Push-Button.** General Electric Co. illustrated bulletin on oil-tight push-buttons.

103 **Speed Changers.** Metron Instrument Co. technical data sheet lists purpose, applications, speed considerations on miniature combination variable and fixed ratio speed changers. Sectional diagrams.

104 **Viscosity Measurement.** Honeywell-Minneapolis Regulator Co. instrumentation data sheet describes Brown ElectroniK recorder and Brookfield Viscometran. Give continuous indication and record viscosity under processing conditions. For food, textile, chemical, and other industries. Illustrations and schematic diagrams.

105 **Valve Line Blind.** Leaflet from D. H. Greenwood on gate valve line blind. Cast steel, built to A.S.A. specifications; O-rings of synthetic rubber for oil industry needs. Wedges unitized.

106 **Valve Actuators.** For installation on valves, valve actuators by Ledeen Mfg. Co. Air, gas, oil, water, or steam-actuated. Direct or remote control. Bulletin illustrated.

107 **Gravity Instruments.** For recording specific gravity of gases, instruments from American Recording Chart Co. Bulletin describes construction, gives ranges, typical gravitometer chart.

108 **Fuel Filtration.** For crude, residual, diesel, refined and gaseous fuels, Winslow Engineering Co. filters. Folder describes method and gives pertinent information.

109 **Gas Analysis Equipment.** Leeds & Northrup Co. Speedomax gas analysis equipment for thermal conductivity measurements. Characteristics, design features, etc. For measuring CO_2, SO_2, O_2 and H_2 purity.

110 **Protective Hoods.** Mine Safety Appliances Co. circular describes Dustfoe dust hood and Gasfoe paint hood. Provide head, eye, face, and neck protection. Also Comfo dust and chmical hoods. Wide-vision plastic windows.

111 **Temperature Controls.** Two temperature control models from Burling Instrument Co. Used primarily for high-temperature safety alarms and cut-outs to 1800° F. Operation, dimensions, method of mounting and operating specifications.

112 **Orifice Meters.** Rockwell Mfg. Co. 201 orifice meters. Bulletin contains 3½ pages of tables of representative orifice capacities for sizing orifice meter plates. Illustrations, descriptions of manifold arrangements, drawings, meter elements.

113 **Fertilizer Plant Design.** Dorr Co. bulletin on design of phosphoric acid, triple superphosphate, ammonium phosphate, and complete concentrated fertilizer plants.

114 **Pyrometer Supplies.** Catalog from Arklay S. Richards Co., Inc. on thermocouples, protection tubes, wire, insulators for all makes of pyrometers. Lists time-saving features, schematic drawings, sizes, materials, etc.

115 **Compressors.** Compressor, valve, and pump line of Pennsylvania Pump and Compressor Co. Details on each type available.

116 **Viscometers.** Norcross Corp. viscometers for recording or recording-controlling of viscosity. Applicable to textile, paper, synthetic, plastic, food industries. Bulletin illustrates models available. Explosion-proof design also.

125 **Transparent Tubing.** Cobon, a transparent plastic tubing from Couse & Bolten Co. Odorless, tasteless, flexible, and nontoxic. Temperature range −30° to 190° F. Sizes 0.12 I.D. to 2 in. I.D. Larger sizes available.

126 **Gear Drive.** Johnson Gear & Mfg. Co. right-angle gear drive for centrifugal pumps and other industrial use Illustrated folder on features including construction, design, lubrication, oil cooler, etc.

127 **Pumps.** Eastman Pacific Co. Dudley V-9 pump for water, brine, oil, gasoline, and chemicals. Positive displacement for pressures to 500 lb./sq.in. Operates at −60 F. to 165° F. No lubrication required. Data and diagrams.

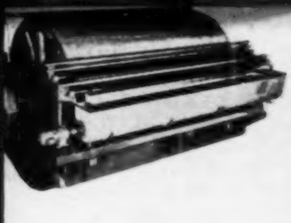
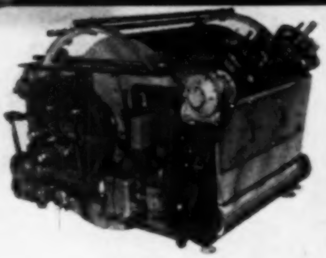
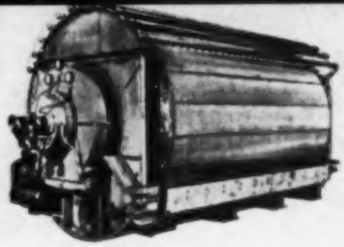
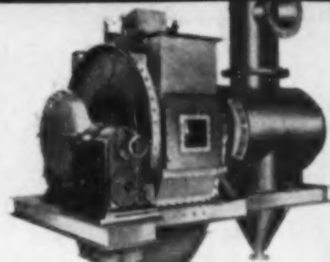
128 **Fabricated Tanks.** Littleford Bros., Inc. tanks fabricated to specifications. Plain, jacketed, code, agitator. Stainless, aluminum, Monel, steel. For the food, chemical, packing and other industries.

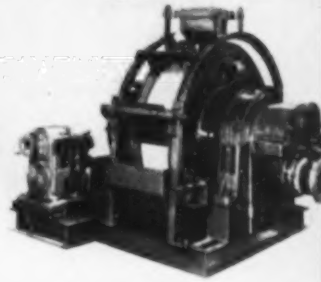
129 **High Pressure Fittings.** High-Pressure Equipment Co. valves, tubes, and fittings. Catalog. Cutaway views, tables of sizes, other information included.

130 **Mixer.** Posey Iron Works, Inc. Lancaster mixer for use where evaporation of liquids, fumes or dust hazard must be avoided.

131 **Stainless Tubing.** Crucible Steel Co. bulletin on stainless tubing. Gives whys and wherefors of all phases. Corrosion data included.

132 **Tray Packing.** Announced by Fractionating Towers, Inc. Multi-Path tray packing. New internal construction for high capacity fractionating columns, absorbers, and countercurrent gas-liquid contacting applications. Easily installed in columns 12 in. I.D. or larger.



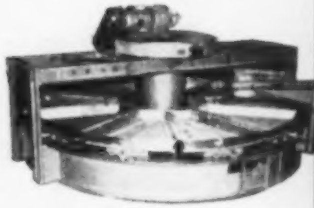
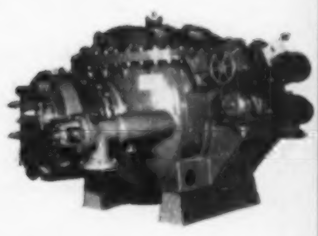
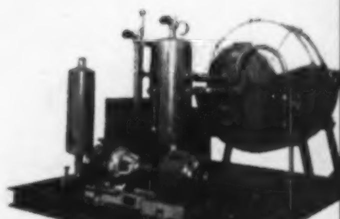
Expert Handling of Every Process Filtration Job Offered by Eimco

Illustrated here are some of the various types of continuous vacuum and pressure filters designed and built by Eimco Engineers.

From the smallest pilot plant filter station to the largest full production plant size filter, Eimco makes all types. We are prepared to test your product and recommend the model best suited to do your job and work efficiently in your flow sheet.

If yours is a simple dewatering job or a complicated selective hot acid separation process there is an Eimco filter that will do the job better, cheaper and faster.

Let engineers, with the experience of Eimco design and operating men behind them, help solve your filtration problems. Write today.

EIMCO A483

THE EIMCO CORPORATION

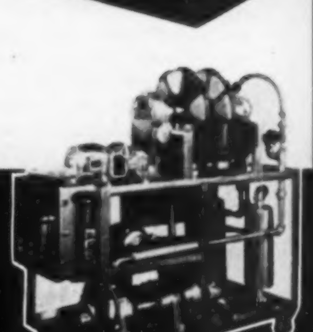
The World's Leading Manufacturer of Vacuum Filtration Equipment

EXECUTIVE OFFICES AND FACTORIES — SALT LAKE CITY 10, UTAH, U. S. A.

BRANCH SALES AND SERVICE OFFICES:

NEW YORK, 51-52 SOUTH STREET • CHICAGO, 3319 SOUTH WALLACE STREET
BIRMINGHAM, ALA., 3140 FAYETTE AVE. • DULUTH, MINN., 216 E. SUPERIOR ST.
EL PASO, TEXAS, MILLS BUILDING • BERKELEY, CALIF., 637 CEDAR STREET
KELLOGG, IDAHO, 307 DIVISION ST. • LONDON W. 1, ENGLAND, 190 PICCADILLY

IN FRANCE: SOCIETE EIMCO, PARIS, FRANCE
IN ENGLAND: EIMCO (GREAT BRITAIN) LTD., LEEDS 12, ENGLAND
IN ITALY: EIMCO ITALIA, S.P.A., MILAN, ITALY



SYMPOSIA

Titles of sessions and their chairmen are:

CARBONIZATION,

R. S. RHODES, asst. mgr., prod. dept., Koppers Co., Inc., Pittsburgh, Pa.

DISTILLATION,

D. E. HOLCOMB, dean of eng., Texas Technological College, Lubbock, Tex.

DRYING,

L. E. STOUT, dean of eng. school, Washington University, St. Louis, Mo.

DUST AND MIST COLLECTION,

C. E. LAPPLE, dept. of chem. eng., Ohio State University, Columbus, Ohio

GENERAL SESSION,

W. E. HESLER, Swenson Evaporator Co., Harvey, Ill.

HEAT TRANSFER,

D. L. KATZ, chairman of dept. of chem. and met. eng., University of Michigan, Ann Arbor, Mich.

INDUSTRIAL WASTE DISPOSAL,

K. S. WATSON, coordinator, waste treatment, mfg. facilities service dept., General Electric Co., Schenectady, N. Y.

PRODUCTIVITY IN CHEMICAL MANUFACTURING,

HENRY E. WESSEL, Midwest Research Institute, Kansas City, Mo.

USE OF ELECTRONIC COMPUTERS IN CHEMICAL ENGINEERING,

JOHN R. BOWMAN, head, dept. of research in physical chemistry, Mellon Institute of Industrial Research, Pittsburgh, Pa.

Student Program

Monday, Dec. 14

9:00 a.m. Student Papers

1:30 p.m. Panel Discussion, "What Career Will You Choose?"

(1) Graduate Work: Dr. D. F. Chamberlain, Washington University. (2) Teaching: Prof. M. S. Peters, University of Illinois. (3) Research and Development: R. V. Newsome, Aluminum Company of America. (4) Design Engineering: H. A. Lutz, Socony-Vacuum Oil Co. (5) Production: Dr. E. D. North, Mallinckrodt. (6) Sales: J. W. Starrett, Monsanto.

EVENING

Theatre Party, Mississippi River Showboat S.S. Goldenrod

Tuesday, Dec. 15

9:00 a.m. Student Papers

12:00 Noon Luncheon (Carl's Rio Room, $2.00). Speaker to be announced later; topic, "Professional Development."

1:30 p.m. Panel Discussion, "Transition from the Scholastic World to the Industrial World."

(1) How to Apply for a Job: L. T. Lanz, Monsanto. (2) Large Versus Small Company Employment: C. R. Smith, Midwest Rubber Reclaiming Co. (3) Evaluating Job Offers: R. C. Sonneman, McDonnell Aircraft Corp. (4) What to Expect on Your Job: A. T. Pickens, C. K. Williams & Co. (5) How You Will be Judged on Your Job: K. B. Bernhardt, Monsanto. (6) How to Succeed on Your Job: J. J. Healy, Jr., Monsanto.

Plant Trips

Typifying the wide spread of chemical products made in the St. Louis area are the fifteen plants and laboratories for which eighteen trips have been scheduled by chairman Stanley L. Lopata, Carboline Co., and his Plant Trips Committee. Preregistration for these trips is desirable due to attendance limitations.

Appropriate to the Plant Trips program is one of the papers in the General Session of the Technical Program: "Process Industries of the St. Louis Area" by Lawrence E. Stout, dean of school of engineering, Washington University, St. Louis.

Anheuser-Busch, Inc., St. Louis, Trip M-1,* 80 men.

This is one of the largest breweries in the world. The trip includes the malt house and germinating drums, wort preparation, fermentation and bottling of finished beer. Other divisions to be shown are the Corn Products department, where dextrines are manufactured, the Research Laboratories and the Food Cabinets department, where deep-freezes and cold storage cabinets are made.

Monsanto Chemical Co., John F. Queeny Plant, St. Louis, Trips M-2 and T-5, 80 men each.

Covering 10 city blocks, this plant makes more than 200 different chemicals, which include pharmaceuticals, intermediates, plasticizers, oil additives, germicides, insecticides, and herbicides. Visitors will be shown the interim manufacturing department, the organic pilot plant, the newly installed research library and Monsanto's latest film release "Decision for Chemistry."

Monsanto Chemical Co., William G. Krummrich Plant, Monsanto, Ill., Trips M-3 and T-4, 75 men each.

Liquid sulfur dioxide, sulfuric acid and oleum are manufactured here. Electrolytic cells produce chlorine, hydrogen and caustic. Evaporators, centrifugals, filters and a power plant will also be seen.

National Lead Co., Titanium Division, St. Louis, Trip M-4, 80 men.

This plant produces white calcium sulfate-titanium dioxide pigment. Large-scale unit operations here are grinding, milling, filtration, calcination and materials handling. Several types of Cottrell precipitators will also be shown.

Nooter Corp., St. Louis, Trip M-5, 80 men.

Visitors will see in action all the steps in custom fabrication of metal, alloy, and clad processing equipment. Highlights: projection of drawings onto materials, automatic flame-cutters and welders, heavy metal-forming equipment, modern machine shop, X-ray inspection, stress-relieving furnace and Metallurgical Research Laboratory.

Procter & Gamble Mfg. Co., St. Louis, Trip M-6, 40 men.

A direct comparison can be made here of the kettle process and the continuous hydrolysis process for manufacture of soap and glycerine. Other items of interest on the tour are towers where quick-dissolving-soap granules are made and packaging and package-handling machinery.

Aluminum Company of America, East St. Louis, Ill., Trip T-1, 75 men.

Plant visitors will observe production operations, a thoroughly equipped modern research laboratory and pilot-scale development facilities. The production plant uses a variety of unit operations and equipment to make alumina, sodium aluminate and fluorides. Great flexi-

(*Continued on page 70*)

* Trips in M-Series are Monday afternoon; T-Series, Tuesday afternoon; W-Series, Wednesday morning.

NEWS

(*Continued from page 32*)

CHEMICAL ENGINEERING FACULTY LIST SOON

The annual list of members of chemical engineering faculties will be available in November, according to Kenneth A. Kobe. The 1953-54 list will contain, in addition to the faculties of all schools in the United States and Canada that grant degrees in chemical engineering, the names of placement officers at the various schools. These names were added at the request of company personnel officers.

STANDARDIZATION IS EXPLAINED BY A.S.A.

A 24-page booklet entitled "Standards Are Your Business" has recently been issued by the American Standards Association to emphasize the economic importance of standardization.

The booklet briefly discusses the savings effected by standardization, the work of the A.S.A., and some achievements of the association. It is available without charge from the A.S.A., 70 East 45 St., New York 17, N. Y.

EXECUTIVES TO DISCUSS COST CONTROL

A symposium on Cost Controls in Operation at which industrial and engineering executives will discuss methods of effective control of costs of research, construction, and production has been announced by the program committee for the Springfield, Mass., meeting of A.I.Ch.E. on May 16 to 19, 1954.

Arranged by chairman D. A. Dahlstrom of Northwestern Technological Institute and cochairman Frank R. Fisher of Sinclair Research Laboratories, the symposium is directed toward executive and management problems of engineers.

Daniel M. Sheehan, vice-president and comptroller of Monsanto Chemical Co., will be the luncheon speaker at this symposium; and M. T. Carpenter, administrative director of Standard Oil Co. (Indiana), Ralph E. DeSimone, chairman of the board and president of Merritt-Chapman & Scott Overseas, Inc., David E. Pierce, consultant (formerly chief engineer of General Aniline & Film Corp.), and L. A. Seder, chief quality control engineer of Gillette Safety Razor Co., will discuss selection of projects, construction costs, importance of type of operation (batch or continuous flow) and instrumentation, and application of statistics to cost control.

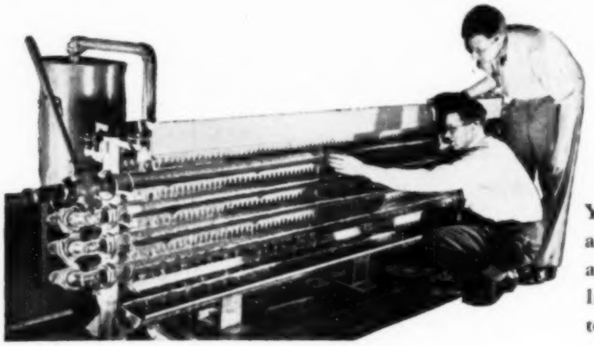
(*More News on page 48*)

Acids can't eat away your PYREX® GLASS processing equipment

Dollar for dollar, no other material has the all-around corrosion resistance of PYREX brand glass No. 7740. Its exceptional mechanical and thermal properties make it ideal for coolers, condensers, fractionating columns, piping and other processing equipment.

What's more, the chemical stability of this PYREX glass provides positive protection against contamination of pharmaceutical and other sensitive products. Transparency permits you to keep an eye on processes—spot defects at a glance. Easy cleaning, another important advantage, results from the hard, smooth surface of glass.

These are only some of the more important reasons why PYREX brand glass pipe, cascade coolers, fractionating columns and other processing equipment pay for themselves many times over. It will pay you to check with Corning.



Pyrex® Cascade Coolers give you two important advantages

The over-all corrosion resistance of PYREX brand cascade coolers offers you two distinct advantages. First, it prevents chemical attack inside the tubes—thus increasing service life. Second, it permits the use of low-cost river or sea water as a coolant.

Low in first cost per BTU transferred, cascade coolers add further economy because the hard, smooth surface of glass limits scale build-up, reduces fouling.

Highly versatile, they can be mounted on floor, wall, or ceiling to conserve space. Shipped complete, a multi-tube unit can be quickly assembled by your own men.

For heat transfer nomographs, tables and description of PYREX cascade coolers, send for Bulletin PE-8.

Good throughput with Pyrex® Columns

You get unusual advantages in solving fractionating and absorption problems with PYREX brand glass fractionating columns. Corrosion resistance assures long service life, low replacement costs. Transparency permits you to observe flow and performance at any stage. Exceptional physical and thermal durability minimize breakage hazards.

Available in 4" and 6" sizes with any number of plates, PYREX fractionating columns have a throughput of 20 to 25 gallons per hour. Gas and liquid samples may be taken at any time without disturbing operation.

Get full information on PYREX fractionating columns and standard packed columns by sending for Data Sheets.

Corning Glass Works
Dept. EP-10, Corning, N. Y.

Please send me:

- ☐ Bulletin PE-8, PYREX brand Cascade Coolers.
- ☐ Data Sheets for PYREX brand Fractionating and Packed Columns.

Name ....
Title ....
Company ....
Address ....
City .... Zone .... State ....

PYREX

Corning means research in Glass

NEWS

(Continued from page 46)

ZIRCONIUM STRIP NOW PRIVATELY PRODUCED

High-purity zirconium strip and other shapes for atomic energy applications have been announced by Allegheny Ludlum Steel Corp. The sponge used by the company is purified by a process developed at the Oak Ridge Laboratories to remove the contaminating element hafnium present in normal zirconium. The small amounts of hafnium limit the usefulness of zirconium for atomic reactors.

The principal problem in melting zirconium, according to Allegheny Ludlum, is the maintenance of the high purity of the sponge, which requires special furnace equipment. Processing from the ingot stage, however, is being accomplished on the company's regular mill equipment. Ingots are shaped in presses or hammers. Hot rolling is done on a 2-high continuous strip mill, and most of the cold rolling utilizes a 4-high reversing strip mill. During hot work zirconium requires lower temperatures than does stainless steel. Temperatures range from 1,500° to 1,800° F.

Experimental work on producing zirconium tubes on a hot extrusion press suggest, according to company engineers, that such production would be practical.

Current maximum capacity for zirconium melting is about 120,000 lb. annually, most of which has been committed.

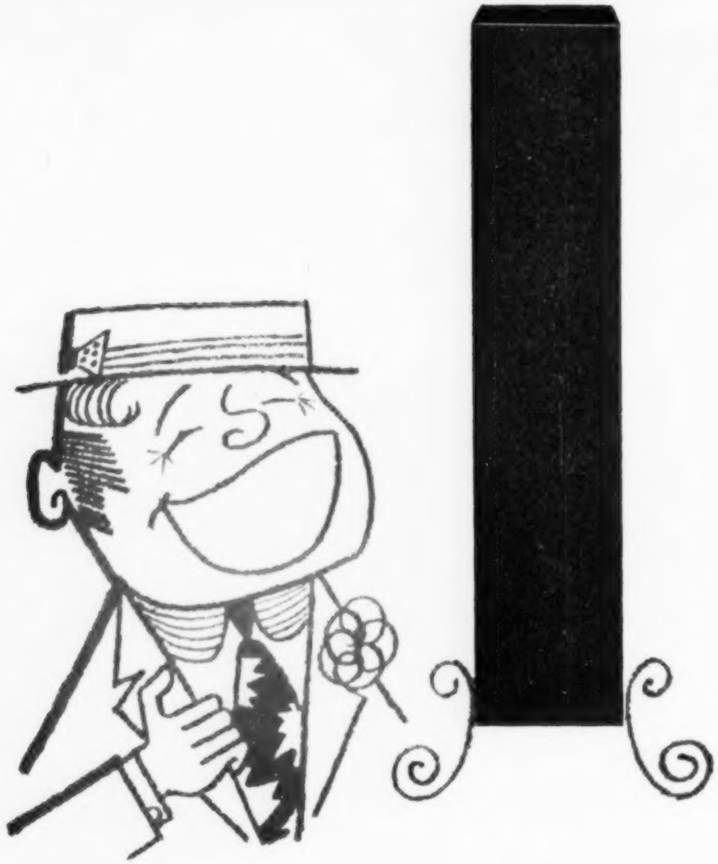
Present production is the result of more than two years of research by Allegheny Ludlum, in cooperation with the A.E.C. Bettis Plant, Pittsburgh, Pa., operated by Westinghouse Electric Corp. The sponge used by the company has been produced by the U. S. Bureau of Mines, but Carborundum Metals Corp. is reported to be constructing a sponge-producing plant that will make privately produced raw material available.

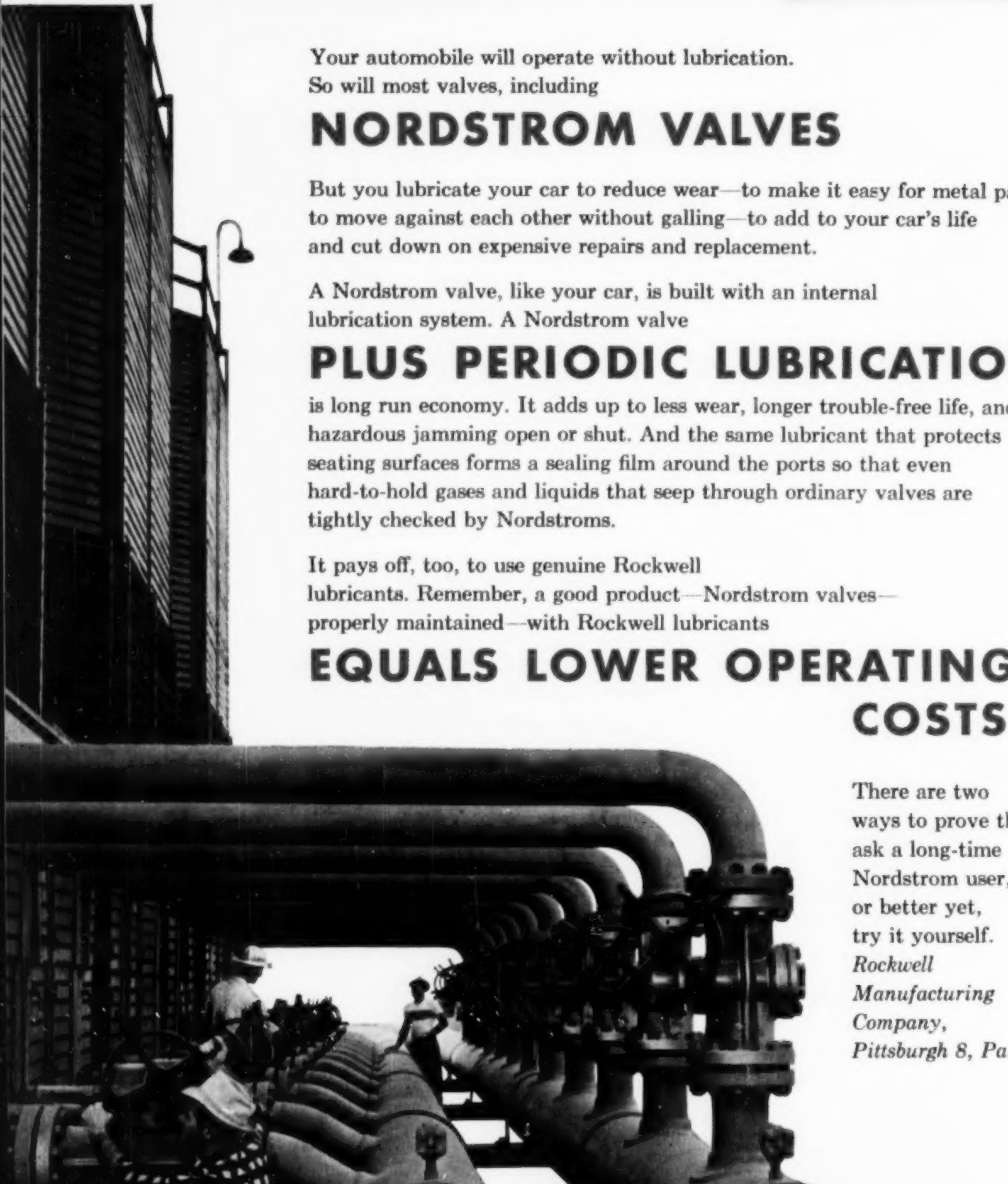
REFINERY SCHEDULED FOR EAST COAST

Pan American Refining Corp. has announced the location of its new East Coast refinery in Goodwin Neck, York County, Va. Construction will be started within six months, and the plant is scheduled for completion in 1955. Initial capacity will be 25,000 bbl. a day.

The American Oil Co., of which Pan American is an affiliate, will distribute all refinery products.

(More News on page 54)





Your automobile will operate without lubrication.
So will most valves, including

NORDSTROM VALVES

But you lubricate your car to reduce wear—to make it easy for metal parts to move against each other without galling—to add to your car's life and cut down on expensive repairs and replacement.

A Nordstrom valve, like your car, is built with an internal lubrication system. A Nordstrom valve

PLUS PERIODIC LUBRICATION

is long run economy. It adds up to less wear, longer trouble-free life, and no hazardous jamming open or shut. And the same lubricant that protects seating surfaces forms a sealing film around the ports so that even hard-to-hold gases and liquids that seep through ordinary valves are tightly checked by Nordstroms.

It pays off, too, to use genuine Rockwell lubricants. Remember, a good product—Nordstrom valves—properly maintained—with Rockwell lubricants

EQUALS LOWER OPERATING COSTS

There are two ways to prove this: ask a long-time Nordstrom user, or better yet, try it yourself.
Rockwell Manufacturing Company, Pittsburgh 8, Pa.

Nordstrom Valves Another Quality **ROCKWELL** Product

NEWS

(Continued from page 48)

PLASTIC-METAL LAMINATE ANNOUNCED

A method of laminating vinyl plastic and sheet steel or aluminum has been developed by the Naugatuck Chemical Division of United States Rubber Co., according to a company announcement. The laminate is made by rolling rigid or semirigid vinyl sheet onto heated adhesive-coated metal sheets or strips. After the rolling, adhesion is effected under heat lamps or other heat source. To date, cold-rolled steel, hot-rolled pickled steels, and aluminum, from 18 to 34 gauge, have been used to make the laminate, the company reports, and the vinyl films used have ranged from 0.002 to 0.02 in. in thickness. Company tests report an adhesion in excess of 40 lb./sq.in.

The structural strength of metal is thus combined with the corrosion and abrasion resistance of plastic, the company emphasizes, to make weatherproof building siding, chemical piping and ducts, and containers for chemicals.

PYRIDINE PRODUCTION AUGMENTED BY 2 FIRMS

Production of pyridine has recently been announced by two companies. U. S. Steel is producing sizable quantities from coal during the high-temperature coking process at its Clairton, Pa., plant, and a new synthetic-pyridine plant is scheduled to be opened in November at Marinette, Wis., by Ansul Chemical Co. This latter plant will produce refined pyridine, alpha picoline, gamma picoline, 2-methyl 5-ethyl pyridine, beta collidine, and a mixture of alkyl pyridine high boilers.

JOINTLY OWNED PLANT OPENED IN CANADA

A new plant was opened last month at Varennes, Quebec, by St. Maurice Chemicals, Ltd., which is jointly owned by Heyden Chemical Corp., New York, and Shawinigan Chemicals, Ltd., Montreal. The new plant has an annual capacity of 30,000,000 lb. of formaldehyde and 3,000,000 lb. of pentaerythritol, the first to be produced in tonnage commercial quantities in Canada, according to the company.

Among the industrial and government leaders of both Canada and the United States who attended the opening ceremony were the Hon. Maurice L. Duplessis, prime minister of Quebec Province, and the Hon. Douglas Stuart, U. S. Ambassador to Canada.

KIRKBRIDE NOMINATED A.I.Ch.E. PRES.—DODGE STEVENSON, V.P. CHOICES

C. G. Kirkbride, president of Houdry Process Corp. and incumbent vice-president of the A.I.Ch.E., was the sole nominee for the office of president for 1954 designated by the members of the Institute during the recent nomination balloting.

However for the office of vice-president, traditionally the stepping stone to the A.I.Ch.E. presidency, six men were nominated. Members gave the required forty-eight nominating votes to B. F. Dodge, professor of chemical engineering, Yale University; E. P. Stevenson, president of Arthur D. Little, Inc.; C. G. Kirkbride; G. G. Brown, dean, College of Engineering, University of Michigan; G. E. Holbrook, assistant director, development department, E. I. du Pont de Nemours & Co., Inc.; and R. C. Gunness, assistant general manager, manufacturing department, Standard Oil Co. (Indiana).

The race narrowed down to Dodge and Stevenson, however, when the four other nominees declined to run. Kirkbride had also been nominated for president; G. G. Brown was nominated as treasurer, the position he holds at present; Holbrook preferred to run for his second term as director; and R. C. Gunness, recently elected a director of the Standard Oil Co. (Indiana), regretted that "after careful consideration it will be impossible for me to accept."

Nominated for treasurer, as mentioned above, was G. G. Brown, and the sole nominee for secretary was S. L. Tyler.

For the four directorships to be filled, however, nineteen men were selected, but because of constitutional provisos, only the first twelve names will appear on the ballot. Biographical sketches of all nominees for director appeared in the August issue; in order of the vote received, the first twelve are as follows: R. P. Dinsmore, G. E. Holbrook, L. P. Scoville, W. A. Cunningham, C. C. Monrad, M. C. Molstad, D. L. Katz, R. N. Shreve, W. L. Faith, L. B. Smith, J. J. Healy, Jr., C. E. Ford.

IMPROVED CELLULOSE FOR RAYON PRODUCTS

A new high-alpha cellulose made by the sulfite process was introduced recently by Rayonier Corp. Coupled with new high-stretch spinning techniques, the product, according to Dr. Arthur N. Parrett, vice-president in charge of research, will possess high fatigue life, high strength, toughness, and resistance to laundering. It is designed primarily for use in high-tenacity tire cord and rayon yarn for textiles.

Cross-section magnification of textile rayon and tire cord shows at upper left thin-skin conventional textile rayon; at upper right medium-skin conventional tire cord; below the new all-skin, high-stretch tire cord manufactured from Rayonier's new chemical cellulose.

The new cellulose is composed of molecular chains of uniform length that in high-stretch spinning are drawn into a highly oriented, crystalline structure throughout the entire filament cross section, company researchers explained. Conventional rayons have this effect, they added, only as an outer skin of the filaments, the core being unoriented, amorphous cellulose; Rayoncord-X, it was stated, is an "all-skin" filament.

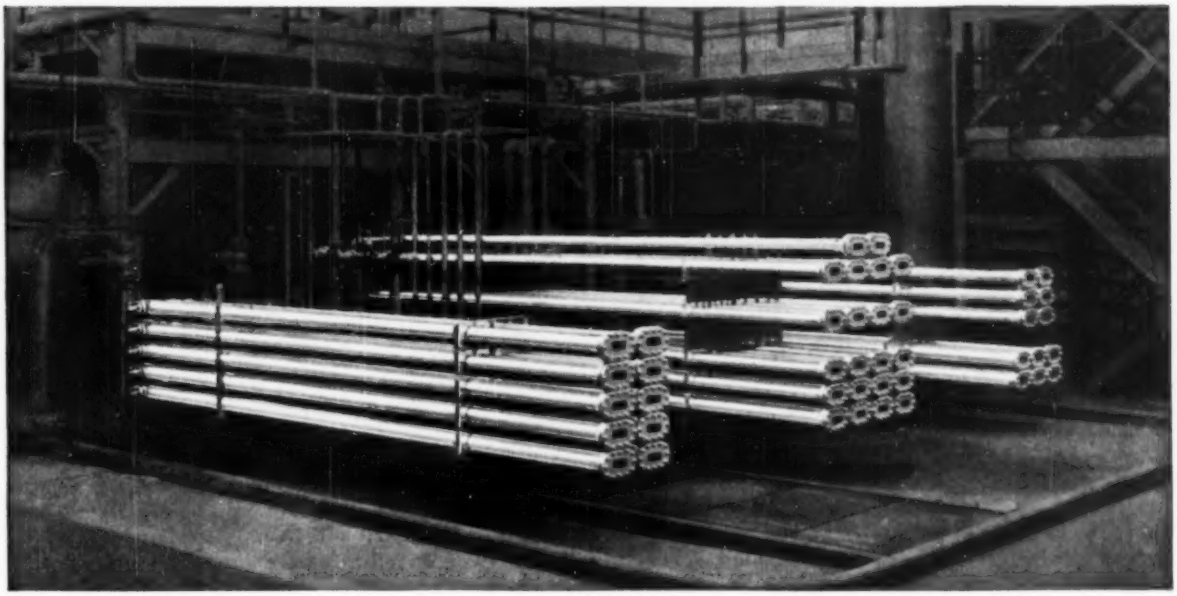
During the high-stretch spinning process the new cellulose, Rayonier emphasized, makes it possible to stretch the filament 100% or more. Untwisted rayon yarns and staple fiber made from the new cellulose by high-stretch spinning processes, it was claimed, possess strengths up to 4 grams per denier, in contrast to 2 grams for ordinary fibers. Also, the new fibers are reported to swell about 75% less when wet.

Rayonier officials stated that despite the rapid growth of the sulfate process of wood cellulose production in recent years, the sulfite process had been selected for production of the new filament. Their nearly completed mill at Jesup, Ga., however, will employ a new process closely akin to the sulfate, or Kraft, process.

(More News on page 66)

Reduce Parts Inventories

in your plant with



BROWN FINTUBE *Sectional* HEAT EXCHANGERS

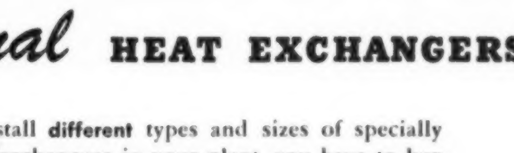
● When you install **different** types and sizes of specially designed, single purpose, heat exchangers in your plant, you have to buy separate sets of parts for **each** exchanger. These parts are costly; and there is the added expense of handling, and storing them.

Unlike these fixed, specially built units, Brown Fintube heat exchangers consist of **Standard Sections** connected in proper series and parallel arrangement. Thus, only a small supply of parts are needed.

In the plant shown above, for example — different groups of Brown Fintube Standard Sections are handling 6 different heat transferring duties — and just a small handful of inexpensive parts serves as adequate stores for all 44 sections. In some cases Brown Fintube Standard Sections have reduced parts inventories **by as much as 82%.**

Reducing inventories is only one of Brown Fintube's many advantages. Our Bulletin 512 gives full details. Send for a copy. We can really save you money!

BROWN FINTUBE CO.
Elyria, Ohio



NEW YORK • BOSTON • PHILADELPHIA • PITTSBURGH • BUFFALO • CLEVELAND • CINCINNATI • DETROIT • CHICAGO • ST. PAUL • ST. LOUIS • KANSAS CITY
MEMPHIS • BIRMINGHAM • NEW ORLEANS • SHREVEPORT • TULSA • HOUSTON • DALLAS • DENVER • LOS ANGELES • SAN FRANCISCO • and ST. THOMAS, ONT.

Another Study of A. I. Ch. E. Questionnaire

Some Correlations on Diverse Subjects

Lloyd B. Smith, J. A. Polack, and G. E. Montes

This analysis is a continuation of the article on the Questionnaire in the September issue. Other studies by the Committee will appear in subsequent issues.

Liberal Arts

Some group within the Institute came forth with the premise that chemical engineers should spend more time on liberal arts courses in academic work. Question 14 was designed to find out what the membership thought about this. Thinking that some of the older Active members in a reminiscent mood might have fathered this thought (toward which the writers are quite sympathetic), the correlation presented in Table 5 was calculated. Here the replies are grouped according to grade of membership—72.1% of the Active members, 68.9% of the Associate members and 67.0% of the Junior members are included, a total of 5,308 members. It the sponsoring group is to be found, further search must be made, for the data show clearly that all grades of membership issued a resounding no to this question, the welfare of posterity notwithstanding.

Registered Engineers

The story of the registered professional engineer is fairly well told in the answers to questions 22 through 25. A slight refinement to the replies to Question 22, "Are you a registered professional engineer?" is given in Table 6 where the responses are classified by grade of membership. Of the 7,719 replies thus classified, about 30% were registered professional engineers and about 70% were not; among those who were registered were 1,435 Active members, or 48.7% of the Active members, 170 Associate members, or 37.1% of this group, and 739 Junior members, or only 17.1%. Thus it seems that the older members find registration more desirable or necessary than the younger group.

Question 23, on the other hand, asked members if registration were important in their work. Only 577 said *yes* compared with the approximately 2,300 that were registered.

Table 5.—Should More Time be Spent on Liberal Arts Courses in Academic Work?

(QUESTION 14 VS. 21)

Question 14 Do you wish that you had spent more time on Liberal Arts, etc.	Replies from Active Members		Replies from Assoc. Members		Replies from Junior Members		Total Replies	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
a. Yes	670	22.9	114	25.0	1178	27.4	1962	25.6
b. No	2107	72.1	314	68.9	2887	67.0	5308	69.0
c. Undecided	145	5.0	28	6.1	241	5.6	414	5.4
Total Replies	2922	100.0	456	100.0	4306	100.0	7684	100.0

Note: Opinion is far more fundamental than any difference in membership grade reflects.

Table 6.—Distribution of Registered Professional Engineers by Grade of Membership

QUESTION 21 VS. 22

Question 22 Are you a registered professional engineer?	Replies from Active Members		Replies from Assoc. Members		Replies from Junior Members		Total Replies	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
a. Yes, in one state only	1245	42.3	152	33.2	688	15.9	2085	27.1
b. Yes, in more than one state	190	6.4	18	3.9	51	1.2	259	3.3
c. No	1511	51.3	288	62.9	3576	82.9	5375	69.6
Total replies	2946	100.0	458	100.0	4315	100.0	7719	100.0

Table 7.—Attendance at Local Section Meetings

(QUESTION 21 VS. 11)

Question No. 11 How active are you in your local section as measured by your average yearly attendance?	Replies from Active Members		Replies from Assoc. Members		Replies from Junior Members		Total Replies	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
a. Have attended none of the meetings.	814	30.7	167	42.3	1427	37.0	2408	34.8
b. Have attended about 25% of meetings.	882	33.2	108	27.3	1163	30.1	2153	31.1
c. Have attended about 50% of meetings.	400	15.1	61	15.4	528	13.7	989	14.3
d. Have attended about 75% of meetings.	435	16.4	48	12.2	576	14.9	1059	15.4
e. Have attended all meetings.	123	4.6	11	2.8	167	4.3	301	4.4
Total replies	2654	100.0	395	100.0	3861	100.0	6910	100.0

Table 8.

Question 28. How many professional or technical people are employed in your company or organization?	Less than 10		10 to 100		101 to 1000		Over 1000		Total		
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent (A)	Per cent (B)
Question 29—Are you, or have you been, an Officer, Director or Committee Member in the National A.I.Ch.E.?											
Yes	26	5.6(A)	81	7.0(A)	213	7.0(A)	166	5.6(A)	486	6.3(A)	....
No	449	94.4(A)	1075	93.0(A)	2831	93.0(A)	2811	94.4(A)	7166	93.7(A)	....
Total number replying	475	100.0(A)	1156	100.0(A)	3044	100.0(A)	2977	100.0(A)	7652	100.0(A)	....
	(475)(B)	(6.2)(B)	(1156)(B)	(15.1)(B)	(3044)(B)	39.8(B)	2977(B)	38.9(B)	7652(B)	......	100(B)
Question 30—Are you, or have you been, an Officer or Committee Member in your Local Section?											
Yes	81	17.2(A)	241	21.2(A)	738	24.5(A)	680	23.0(A)	1740	22.8(A)	....
No	391	82.8(A)	900	78.8(A)	2280	75.5(A)	2267	77.0(A)	5838	77.2(A)	....
Total number replying	472	100.0(A)	1141	100.0(A)	3018	100.0(A)	2947	100.0(A)	7578	100.0(A)	....
	(472)	(6.2)(B)	(1141)	(15.1)(B)	(3018)	(39.8)(B)	2947	38.9(B)	7578	......	100(B)

Question 24 asked if the members said *no* to Question 22, then were they registered as an "Engineer in Training," but only 8% said *yes*.

Question 25 asked if the members were not registered now, did they expect to become registered. About 27.5% or 1,440, replied *yes* to this question. Added to the 30% who are now registered, future registration might be around 57%.

Local Sections

Question 10 stated, "If you are a member of a local section, please check." It is gratifying that out of the 7,802 replying, 4,953 did so. While this is 63.5% of those who had interest enough to mail back the completed questionnaire, one wonders why the remaining 36.5% are not members of local sections. In the subsequent parts of Question 10, the 2,692 responses give us some clues.

a. 33.8% of the non-members claimed commuting difficulties as a reason. One suspects that some may use this situation as an alibi rather than a reason. It is hard to reconcile the comment from New York City that too much time is required to cross town to attend a meeting with the fact that frequently four to six members drive 80 miles or more to a meeting of the Baton Rouge Section—and drive back home the same night. Nevertheless it is realized that for many, commuting difficulties are real problems.

b. 9.3% have not been asked to join. This situation surely can be remedied.

c. 8.6% frankly are not interested, which is their privilege. Perhaps they could become interested, regardless.

d. & e. It is a comfort to know that the answers to these two questions "Section dues are too high" and "Don't like the group" average less than 1%.

f. 19.4% did not know of a near-by local section. Several written-in comments also mentioned this lack. In lieu of local sections in sparsely populated (with Ch.E.'s) areas, it is suggested that consideration be given to state organizations with say, quarterly meetings.

g. 6.7% had no opinion. No comment!

h. 20.6% had some other reason. The written-in comments showed these to be quite varied, for example, "new in the area," "move around a lot," and "wife expecting a baby."

Question 11 was directed to the local section members and asked, "How active are you in your section yearly?" The answers to this question were separated according to grade of membership, and are presented in Table 7.

There are three sets of significant figures in Table 7. The average yearly attendance at more than half the meetings was about 34%.

4.4% attended all meetings.
15.4% attended 75% of meetings.
14.3% attended 50% of meetings.

34.1% average attendance at more than half the meetings.

Among those who attended more than half the meetings there was not much, if any, difference by grade of membership, i.e.,

Attendance of Active members at more than half the meetings was 36.1%
Attendance of Associate members at more than half the meetings was 30.4%
Attendance of Junior members at more than half the meetings was 32.9%

Those who attended none of the meetings, were, in the order of their inactivity:

42.3% of Associate members
37.0 of Junior members
30.7% of Active members.

Question 12 asked, "Why do you attend the local section meetings?" Of the 5,242 responses received,

32.6% enjoyed personal contacts and social gatherings.
29.4% were interested in technical problems.
28.5% felt it helped professionally.

Thus twice as many felt personal contacts and professional development were important as did those who attended because of the technical problems discussed.

Question 13 asked, "Why do you miss Local Section Meetings?" Replies were not particularly productive, as 45% had "other engagements" and 22% were "not interested in the program."

Questions 29 and 30 were intended to measure the interest and activity of members at both the national and local level by the number that had served in some office or on some committee. These results are tabulated in Table 8 and are correlated against the sizes of companies represented.

At the national level 486 or 6.3% had held office or served on a committee, but 7,166 or 93.7% had not. Particularly striking is the close agreement with this average of companies of all sizes.

At the local level, the participation in offices or on committees was three and one-half times as high as the national figures indicate, the average being 22.8% participation and 77.2% non-office holders or non-committee members. The agreement with this average among companies of all sizes was good, but not as close as at the national level, and the smaller companies apparently did not show up quite as well in this comparison.

Candidates for Membership in A.I.Ch.E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 7, of the Constitution.

Objections to the election of any of these candidates from Active Members will receive careful consideration if received before November 15, 1953, at the Office of the Secretary, American Institute of Chemical Engineers, 120 East 41st Street, New York 17, N. Y.

Applicants for Active Membership

Abernathy, Fred R., *Kingsport, Tenn.*
Addoms, James N., *Arlington, Mass.*
Antonio, Adolph L., *Azusa, Calif.*
Batey, Robert W., *Minneapolis, Minn.*
Bell, R. S., *Richland, Wash.*
Benner, Roland G., *Summit, N. J.*
Cobb, John E., Jr., *Victoria, Tex.*
Day, Henry C., *Plainfield, N. J.*
Eaton, H. Burton, Jr., *Pennsgrove, N. J.*
Files, John T., *Houston, Tex.*
Gammell, Don M., *San Franciso, Calif.*
Haag, Chas. R., *Cranford, N. J.*
Harper, John C., *Los Angeles, Calif.*
Johnson, Hal G., *Atherton, Calif.*
Koons, Russel D., *Redondo Beach, Calif.*
Lantos, Peter R., *Wilmington, Del.*
Lippa, Shepherd, *Shelton, Conn.*
Lyons, Frank H., *Memphis, Tenn.*
Manning, W. R., *So. Charleston, W. Va.*
Marsh, Sam, *Cranston, R. I.*
McKinney, John W., *Wilmington, Del.*
Meinrath, August Herman, *Corpus Christi, Tex.*
Newburn, Floyd A., *Arcadia, Calif.*
Park, John K., *Ashton, R. I.*
Rosen, Bernard H., *Massapequa, N. Y.*
Sagenkahn, Malcolm L., *Concord, Calif.*
Schleck, Richard C., *Pittsburgh, Pa.*
Shaw, William E., *Cincinnati, Ohio*
Shervem, Robert M., *Richland, Wash.*
Thober, Herbert C., *Toledo, Ohio*
Tsunoda, Kenneth, *New York, N. Y.*
Yelton, Everett B., *Orange, Tex.*
Zimmerer, Robert I., *So. Charleston, W. Va.*

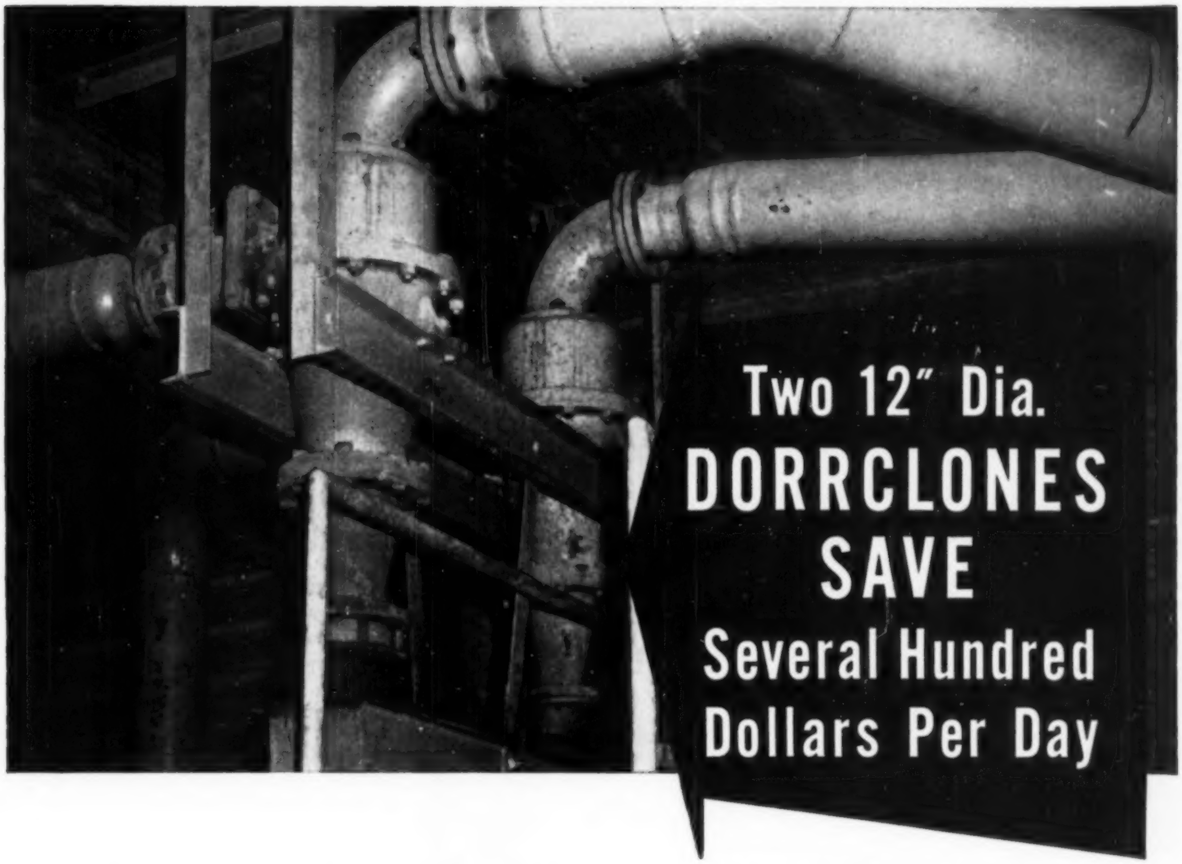
Applicants for Associate Membership

Donley, Edward, *Emmaus, Pa.*
Koch, Edward J., *Brevard, N. C.*

Applicants for Junior Membership

Anderson, Ronald L., *Baytown, Tex.*
Apkenas, V. P., *Los Angeles, Calif.*
Beadle, Burton J., *Lake Charles, La.*
Bernabei, Raymond R., *Yonkers, N. Y.*
Berry, Charles A., *Mamaroneck, N. Y.*
Blanc, Fernando E., *Santiago de Cuba, Cuba*
Blanchard, Kenneth O., *Wilmington, Del.*
Blum, Edmund D., *Elgin, Ill.*
Bochinski, Julius, *Ames, Iowa*
Bush, Warren V., *Montclair, N. J.*

(*Continued on page 60*)


Two 12" Dia.
DORRCLONES
SAVE
Several Hundred
Dollars Per Day


DorrClone

CANDIDATES

(Continued from page 58)

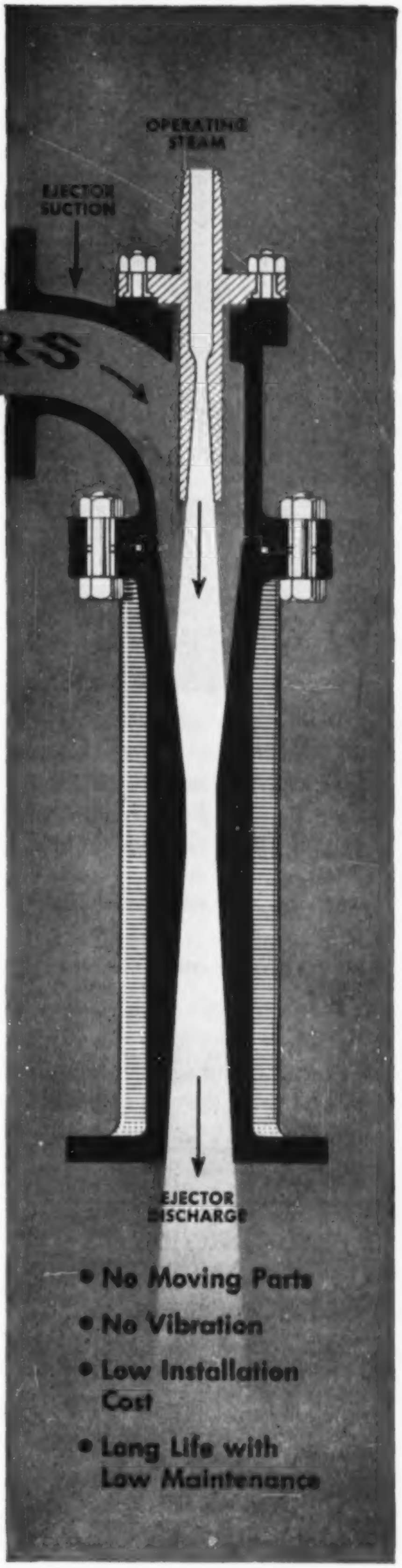
Carvey, Robert M., *East Alton, Ill.*
Choate, B. L., *Houston, Tex.*
Clarke, James, *Camden, S. C.*
Coffey, Richard A., Jr., *Springfield, Mass.*
Davis, Robert L., *Pennsville, N. J.*
Deprez, Andre C., *Cambridge, Mass.*
Diehr, J. Allan, *Hazel Park, Mich.*
Dornheim, Fred R., *Harvey, Ill.*
Dwyer, Francis G., *Philadelphia, Pa.*
Feeney, H. Donald, *Wilmington, Del.*
Forester, George A., *Freeport, Tex.*
Forstall, Lloyd M., *Whiting, Ind.*
Foster, Charles F., *So. Charleston, W. Va.*
Freebersyser, George J., *St. Louis, Mo.*
Froehlich, Leonhard H., *Loganville, Wisc.*
Gilbert, Thomas E., *Schenectady, N. Y.*
Gorcyca, Edwin F., *Texas City, Tex.*
Grover, John H., *Alexandria, Va.*
Hardt, Alexander P., *Berkeley, Calif.*
Harmon, Dale Lynn, *Charleston, W. Va.*
Hartung, Donald E., *Chicago, Ill.*
Hein, E. David, *Detroit, Mich.*
Hinkle, Barton L., *Richmond, Va.*
Irwin, Howard W., *Cumberland, Md.*
Kamenko, Gus C., *East St. Louis, Ill.*
Krimbill, Harry W., Jr., *Tulsa, Okla.*
Laegreid, Sigbjorn, *Rochester, N. Y.*
Leoshko, George, *Ann Arbor, Mich.*
Levine, Daniel M., *Los Angeles, Calif.*
Lieberman, Jerry M., *Brooklyn, N. Y.*
Lipuma, Charles R., *Newark, N. J.*
Makray, Tamas, *Rio de Janeiro, Brazil*
Manspeaker, John R., *Benton, Kans.*
McCarty, Richard H., *Bronx, N. Y.*
McDonald, Fred, *Baytown, Tex.*
McLaurin, A. J., *Houston, Tex.*
Miller, C. Donald, *Charleston, W. Va.*
Mitchell, William J., *Rochester, N. Y.*
Muraski, Frank T., *Portsmouth, Ohio*
O'Connell, Gerald D., *Hicksville, N. Y.*
Otstot, Roger Sherman, *Raleigh, N. C.*
Page, William H., *Madison, Wisc.*
Popielski, Daniel A., *Springfield, Mass.*
Reed, Thomas, Jr., *Lake Jackson, Tex.*
Reichle, Walter T., *Bloomfield, N. J.*
Rogers, Milton B., *Louisville, Ky.*
Rosett, L. Kenneth, *Tuckahoe, N. Y.*
Saunderson, George F., *Downey, Calif.*
Schablow, Kenneth P., *West Allis, Wisc.*
Schepman, Berne A., *Roselle, N. J.*
Schneider, Alfred, *Jackson Heights, N. Y.*
Short, Mary A., *Camp Detrick, Md.*
Smith, Allan H., *China Lake, Calif.*
Sokoloff, Sergio, *Bogota, Columbia*
Tate, John, *Decatur, Ala.*
Trice, Virgil G., Jr., *Lemont, Ill.*
Utley, James F., *Brandenburg, Ky.*
Van Tassell, Harry M., *Atlanta, Ga.*
Vogel, Carl H., *New Providence, N. J.*
Wallace, Paul C., *Louisville, Ky.*
Walton, Thomas H., *Laurel, Miss.*
Westermann, Donald H., *Cudahy, Wisc.*
Williams, Alfred Eugene, *Buffalo, N. Y.*
Wolker, Elzie, *Levittown, Pa.*
Wollscheid, D. E., *Niagara Falls, N. Y.*
Youngblood, Enoch Lloyd, Jr., *Oak Ridge, Tenn.*

for low-cost suction pressures

EVACUATE BY STEAM

with

I-R STEAM-JET EJECTORS



Where processes call for vacuum pressures down to 50 microns (.002" Hg abs), the I-R Steam Jet Ejector can generally make important savings in first cost, installation, operation and maintenance.

The steam jet ejector is the ultimate in mechanical simplicity, consisting of only three basic parts—a steam nozzle, a suction chamber and a venturi-shaped diffuser. There are no moving parts to wear out or require lubrication—no vibration—nothing to adjust or replace. Little or no foundation is required and space requirements are very moderate.

Ingersoll-Rand can supply Steam Jet Ejectors, designed for any capacity requirements within their vacuum pressure range. They will handle wet or dry mixtures of air, gases and vapors, and accidental entrainment of liquid will do no damage. I-R Ejectors are available in single-stage, two-stage, and multiple-stage designs—with pre-coolers, intercondensers and after condensers as required for any specific application.

Remember, I-R engineers are specialists in vacuum-producing equipment—including both steam-jet ejectors and reciprocating vacuum pumps. Their recommendations for *your* vacuum equipment are therefore based solely on your own best interests. For further information, consult your nearest I-R representative. Or write for a free copy of Bulletin 9013A.

Ingersoll-Rand

11 BROADWAY, NEW YORK 4, N. Y. 843-4

COMPRESSORS • AIR TOOLS • ROCK DRILLS • TURBO-BLOWERS
CONDENSERS • CENTRIFUGAL PUMPS • DIESEL AND GAS ENGINES

Secretary's Report

S. L. TYLER

The Executive Committee transacted the necessary business for the months of August and September by mail ballot. Minutes of the previous meeting were approved as issued. Secretary reported that no adverse comment had been received regarding the applicants for membership whose names appeared in the July and August issues of "C.E.P.," and they were therefore declared elected to the grades of membership for which they applied. Treasurer's reports of June 30 and July 31 were received and approved. Three resignations were accepted.

S. G. Pappas was placed on the Suspense List because he entered the Armed Forces.

J. L. Martine, representing the St. Louis Section, was appointed to the Membership Committee to succeed Aaron Rose, also J. Walkey, representing the Northern California Section, was appointed to succeed T. E. Driscoll, Jr.; A. S. Hall, representing the New Orleans Section, was appointed to the Public Relations Committee to succeed H. J. Janssen, and William Shuster, representing the Northeastern New York Section, was appointed.

The Council met at the Fairmont Hotel, San Francisco, Calif., on Sept. 12, and minutes of previous meetings as well as those of the Executive Committee were received and approved.

The statement reporting on the operations of the Institute for the first six months of 1953 was approved; it was found to be in line with the budget as approved earlier.

The chairmen of the standing committees of the Institute for 1954 were appointed.

Questions pertaining to membership grades, voting franchises, and other matters dealing directly with the membership of the Institute, which had been before the Council for several meetings, were further discussed. A few tentative decisions were made, and the matters were submitted to the Constitution and By-Laws Committee with the request that a study be made with the thought in mind of possible amendment to the Constitution.

E. P. Stevenson, chairman of the Institute Housing Committee, reported in detail on the activities of the committee. His recommendation was that the Institute investigate the matter of obtaining headquarters in its own building in New York City. Preliminary investigations indicate clearly that such

(*Continued on page* 64)

SECRETARY'S REPORT

(Continued from page 62)

a headquarters could be operated much more economically than continuing to rent space in commercial buildings. On the basis of the preliminary report of the Committee, Council authorized further study and a definite recommendation to be brought in as soon as possible.

The establishment of Divisions of the Institute based on special interests or fields of activity in chemical engineering had been proposed and referred to the Constitution and By-Laws Committee. This committee reported that it would recommend the establishment of divisions, and therefore it was requested to prepare an amendment to the Constitution.

Upon recommendation of the Program Committee, the dates of March 20-23, 1955, were approved for the holding of a national meeting of the Institute at Louisville, Ky.; the dates of May 1-4, 1955, were approved for the national meeting at Houston, Tex.

The question of the trend which is developing in this country towards the organization of professional employees, engineers, and others into bargaining groups having practically the same status as labor unions was discussed. Reports of activities in various parts of the country were presented and a special committee was appointed to study such procedure and report.

Upon recommendation of the Student Chapters Committee, the establishment of a student chapter at Louisiana Polytechnic Institute was approved.

The report of the Chemical Engineering Education and Accrediting Committee was received, and actions were taken in accordance with its recommendations. These actions will be reported to the Engineers' Council for Professional Development with the request that it act accordingly.

The Tellers Committee, consisting of the following—F. B. White, chairman, S. Adler, W. Dorsheimer, H. Malakoff, R. Morton and S. J. Wolff, secretary, had completed their count of the Nominating Ballot and the report was presented to the Council. An election ballot will be prepared and distributed based upon acceptance of the nominations.

FOLSOM HEADS ENG. RES. INSTITUTE AT ANN ARBOR

The president and the regents of the University of Michigan, Ann Arbor, recently announced the appointment of Richard Gilman Folsom, Ph.D., as director of the Engineering Research Institute effective Sept. 1, 1953.

NEWS

(Continued from page 54)

DU PONT STARTS NEW ILMENITE PLANT

Construction of a $3,000,000 mine and plant to produce ilmenite near Lawtey, Fla., was announced recently by Du Pont. To be known as the Highland plant, the installation will be built and operated by the Humphreys Gold Corporation of Denver, which expects to complete construction early in 1955.

Ilmenite is the principal titanium-bearing ore available to industry. The metallic element titanium is difficult to extract from ilmenite, which is composed principally of iron oxides and titanium and exists in three principal types of ore: sand, rock, and slag.

The Du Pont operation is concerned with ilmenite in sand and requires a dredge floating on a "traveling lake" about a half mile long and 500 ft. wide dug out of the sandy soil. A dredge and separators floating on the lake pick up the sand in front, take out the black ilmenite, and pour the sand back in again behind them. The lake thus travels forward in the direction of the work—moving in where sand is removed and being pushed forward by the sand returned in back.

A suction dredge pulls the sand up and pipes it directly to a floating scrubber barge, where the organic coating is removed and the heavy black mineral is separated from the white sand by a system of spirals in a wet mill. The spiral system was originally devised by Humphreys as an improved method of concentrating gold sands.

The concentrated ore is piped to a dry mill on land, where the ilmenite is further concentrated by electromagnetic and electrostatic separators and shipped to processing plants in Maryland and Delaware. Output of Du Pont's present plant, the Trail Ridge, is about 100,000 tons annually, and the capacity of the new plant will be the same.

The percentage of ilmenite in sand is about 2 per cent.

CHEMICAL ENGINEERING DEPARTMENT AT SEATTLE

A newly constituted department of chemical engineering at the University of Washington, Seattle, Wash. was recently announced by the Board of Regents of that university. Although chemical engineering heretofore was under the jurisdiction of the College of Engineering, it was joined with chemistry in the College of Arts and Sciences under a single departmental title and executive officer. The new department will be headed by R. Wells Moulton (*see* page 79).

FUTURE MEETINGS AND SYMPOSIA OF A.I.Ch.E.

Chairman of the A.I.Ch.E. Program Committee

Loren P. Scoville, Jefferson Chemical Company, Inc. 260 Madison Ave., New York 16, N. Y.

MEETINGS

Annual—St. Louis, Mo., Hotel Jefferson, Dec. 13-16, 1953.

TECHNICAL PROGRAM CHAIRMAN: J. J. Healy, Jr., Assist. to V. P., Monsanto Chemical Co., 1700 S. 2nd St., St. Louis 4, Mo.

Washington, D. C., Statler Hotel, March 8-10, 1954.

TECHNICAL PROGRAM CHAIRMAN: George Armistead, Jr., Consult. Chem. Eng., George Armistead & Co., 1200 18th St. N.W., Washington 6, D. C.

Springfield, Mass., Hotel Kimball, May 16-19, 1954.

TECHNICAL PROGRAM CHAIRMAN: E. B. Fitch, Asst. to Res. Dir., The Dorr Co., Westport, Conn.

Ann Arbor, Mich., Univ. of Mich., Ann Arbor, Mich., June 20-25, 1954—Conference on Nuclear Engineering.

TECHNICAL PROGRAM CHAIRMAN: D. L. Katz, chairman, Dept. of Chem. and Met. Eng., Univ. of Mich., 2028 E. Eng. Bldg., Ann Arbor, Mich.

Glenwood Springs, Colo., Hotel Colorado, Sept. 12-15, 1954.

TECHNICAL PROGRAM CHAIRMAN: Prof. C. H. Prien, Dept. of Chem. Eng., Univ. of Denver, Denver 10, Colo.

Annual—New York, N. Y., Statler Hotel, Dec. 12-15, 1954.

TECHNICAL PROGRAM CHAIRMAN: G. T. Skaperdas, Assoc. Dir., Chem. Eng. Dept., M. W. Kellogg Co., 225 Broadway, N. Y. 7, N. Y.

ASST. CHAIRMAN: N. Morash, Titanium Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

Louisville, Ky., Kentucky Hotel, March 20-23, 1955.

TECHNICAL PROGRAM CHAIRMAN: R. M. Reed, Tech. Dir., Gas Proc. Div., The Girdler Corp., Louisville 1, Ky.

Houston, Texas, Shamrock Hotel, May 1-4, 1955.

TECHNICAL PROGRAM CHAIRMAN: J. L. Franklin, Res. Assoc., Humble Oil & Refining Co., P. O. Box 1111, Baytown, Texas.

Lake Placid, N. Y., Lake Placid Club, Sept. 25-28, 1955.

TECHNICAL PROGRAM CHAIRMAN: L. J. Coulthurst, Chief Proc. Designer, Foster Wheeler Corp., 165 Broadway, New York 6, N. Y.

Detroit, Mich.—Statler Hotel, Nov. 27-30, 1955.

TECHNICAL PROGRAM CHAIRMAN: T. J. Carron, Head, Chemical Tech. Office, Ethyl Corp., Res. Labs., 1600 West Eight Mile Road, Detroit 20, Mich.

SYMPOSIA

SYMPOSIA FOR ST. LOUIS MEETING

Distillation

Dust and Mist Collection

Drying

Use of Computers in Chemical Engineering

Heat Transfer

Carbonization

Industrial Waste Disposal

Mixing

CHAIRMAN: J. H. Rushton, Dept. of Chem. Eng., Illinois Inst. of Tech., Chicago, Ill.

MEETING—Washington, D. C.

Patents

CHAIRMAN: W. C. Asbury, V. P., Std. Oil Dev. Co., 15 W. 51st St., New York 19, N. Y.

MEETING—Washington, D. C.

Chemical Engineering in the Fertilizer Industry

CHAIRMAN: G. L. Bridger, Head, Dept. Chem. & Mining Eng., Iowa State College, Ames, Iowa.

MEETING—Washington, D. C.

Liquid Entrainment and Its Control

CHAIRMAN: H. E. O'Connell, Ethyl Corp., P. O. Box 341, Baton Rouge, La.

MEETING—Washington, D. C.

Chemical Engineering Fundamentals

CHAIRMAN: R. A. Kinckiner, E. I. duPont deNemours & Co., Wilmington, Del.

MEETING—Washington, D. C.

New Metal Technology

CHAIRMAN: W. C. Schroeder, U. S. Bureau of Mines, Dept. of the Interior, Washington 25, D. C.

MEETING—Washington, D. C.

Polymeric Materials of Construction

CHAIRMAN: C. C. Winding, Assist. Dir., College of Eng., Cornell Univ., Ithaca, New York.

MEETING—Springfield, Mass.

Nuclear Engineering

CHAIRMAN: D. L. Katz, Chairman (Address: See Ann Arbor Meeting).

MEETING—Ann Arbor, Mich.

Reaction Kinetics

CHAIRMAN: N. R. Amundson, Dept. of Chem. Eng., Univ. of Minnesota, Minneapolis 14, Minn.

MEETING—New York, N. Y.

Gas Absorption

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

MEETING—New York, N. Y.

Centrifugation

CHAIRMAN: J. O. Maloney, Chairman, Dept. Chem. Eng., Univ. of Kansas, Lawrence, Kan.

Nucleation Processes

CHAIRMAN: E. L. Piret, Dept. Chem. Eng., Univ. of Minn., Minneapolis 14, Minn.

Agglomeration

CHAIRMAN: A. P. Weber, International Engineering, Inc., 15 Park Row, New York, N. Y.

Solvent Extraction

CHAIRMAN: Dr. R. B. Beckmann, Dept. Chem. Eng., Carnegie Inst. of Tech., Schenley Park, Pittsburgh 13, Pa.

Submitting Papers

Members and nonmembers of the A.I.Ch.E. who wish to present papers at scheduled meetings of the Institute should follow the following procedure.

First, write to the Secretary of the A.I.Ch.E., Mr. S. L. Tyler, American Institute of Chemical Engineers, 120 East 41st Street, New York, requesting three copies of the form "Proposal to Present a Paper Before the American Institute of Chemical Engineers." Complete these forms and send one copy to the Technical Program Chairman of the meeting for which the paper is intended, one copy to the Chairman of the A.I.Ch.E., Program Committee, address at the top of this page, and one copy to the Editor of Chemical Engineering Progress, Mr. F. J. Van Antwerpen, 120 East 41st Street, New York.

If you wish to present the paper at a particular symposium, one copy of the form should go to the Chairman of the symposium instead of the Technical Program Chairman of the meeting.

Before Writing the Paper

Before beginning to write your paper you should obtain from the meeting Chairman, or from the office of the Secretary of the A.I.Ch.E., at 120 East 41st St., New York, a copy of the A.I.Ch.E. Guide to Authors, and Guide to Speakers. These cover the essentials required for submission of papers to the A.I.Ch.E. or its magazines.

Copies of Manuscript

Five copies of each manuscript must be prepared. For meetings, one should be sent to the Chairman of the symposium, and one to the Technical Program Chairman of the meeting at which the symposium is scheduled. If no symposium is involved, the two copies should be sent to the Technical Program Chairman. The other copies should be sent to the Editor's office since manuscripts are automatically considered for publication in Chemical Engineering Progress, or the symposium series of Chemical Engineering Progress, but presentation at a meeting is no guarantee that they will be accepted.

DEADLINE DATES FOR PAPERS

ST. LOUIS MEETING—(Passed)

WASHINGTON, D. C. MEETING—November 8, 1953

SPRINGFIELD MEETING—January 9, 1954

ANN ARBOR MEETING—February 15, 1954

GLENWOOD SPRINGS MEETING—May 12, 1954

NEW YORK MEETING—August 12, 1954

LOUISVILLE MEETING—November 20, 1954

HOUSTON MEETING—definite dates have not been set.

LAKE PLACID MEETING—May 25, 1955

DETROIT MEETING—July 27, 1955

LOCAL SECTION

ST. LOUIS

The fall program of the St. Louis Section opened with a smoker Sept. 17, 1953, at the Hyde Park plant of Griesedieck-Western Brewery in St. Louis, with 120 members and guests in attendance. The entertainment committee uncorked a well-received "mixing" stunt which culminated in the awarding of tokens of the occasion to four grinning winners. Several members demonstrated their ham-carving prowess and unsuspected catering talents while serving a buffet dinner. Early arrivals were escorted through the plant of the host company. Stories on vacation experiences were swapped and some members informally discussed their committee duties for the annual A.I.Ch.E. meeting to be held in St. Louis in December.

AKRON

The Akron Section held its annual fall picnic on Sept. 18 at the M. A. Knight Estate. Members and guests numbering 140 enjoyed card-playing, volley ball, and other sports activities.

The beginning of the fall season is scheduled to open with the Oct. 8 dinner meeting at the local Y.M.C.A. Dr. Henry B. Hass, president of the Sugar Research Foundation, Inc., will speak on the subject "Commonest Pure Organic Compound." Dr. Hass was formerly research director of the Baltimore Gas Engineering Corporation of Charleston, W. Va., and was associated with the Manhattan Project in the development of fluorocarbons from 1942 to 1946.

NEW ORLEANS

The New Orleans Section of A.I.Ch.E. held a meeting at the Engineers and Architects Club of New Orleans on Sept. 15. Dr. Robert Nieset, professor of physics at Tulane University, was speaker of the evening. Dr. Nieset's talk included a discussion of the use of both stable and radioactive isotopes in process control and exploration.

OHIO VALLEY

The Ohio Valley Section held its first meeting of the season on Sept. 18, at the Engineering Society headquarters in Cincinnati. The speaker for the evening was Don Clark of the Sun Oil Co. A film was shown titled "2 = 3." It was produced by the Oil Industry Information Committee of the American Petroleum Institute and dealt with improvements in the production and quality of motor fuels.

PLANT TRIPS

(*Continued from page 44*)

bility in use is built into the development equipment.

American Zinc Company of Illinois, Zinc Smelter, Fairmont City, Ill., Trip T-2, 60 men.

Slab zinc, 66° Be. sulfuric acid and by-products are manufactured here by processes of interest to engineers. Zinc concentrate is roasted in Herreshoff and flash roasters; the gases go to the sulfuric acid contact process. After sintering, grinding, and classifying calcines, zinc is distilled in retorts.

International Shoe Co., Tannery, Wood River, Ill., Trip T-3, 33 men.

Hide preparation, tanning by both chrome and vegetable processes and finishing of leather to uniform thickness for shoe uppers will be shown. This is one of the largest tanneries in the United States.

Socony-Vacuum Oil Co., Inc., East St. Louis, Ill., Trip T-6, 66 men.

Interesting equipment and instrumentation here process 1,400,000 gal./day of crude oil to gasoline, jet fuels, kerosene, Diesel oil, heating oils, etc. Two kinds of catalytic reactors (Houdry fixed bed and a T.C.C. unit) are in use.

Washington University Cyclotron and Engineering Laboratories, St. Louis, Trip T-7, 40 men.

The cyclotron, one of the largest of its type in the world, has an 80-ton magnet 10 ft. high, with a 12-ton winding. For some purposes it is equivalent to 7 tons of radium. First operated in 1942, it is now used for A.E.C., N.E.P.A. and Office of Naval Research projects.

Chemical engineering seniors will show visitors the electrical, civil, mechanical, and chemical engineering laboratories.

Missouri Portland Cement Co., St. Louis, Trip T-8, 80 men.

Visitors will see the new 6,500 bbl./day cement plant in operation. Features are modern storage, conveying and feeding systems, 1,000 hp. ball mills and tube mills, 180-200 ft. diameter Dorr thickeners, 11 ft. 3 in. diam. × 450 ft. long rotary kilns, 100 ft. long grate coolers and large Cottrell precipitators.

American Zinc Company of Illinois, Electrolytic Zinc Plant, Monsanto, Ill., Trip W-1, 60 men.

This plant produces 110 tons/day of 99.99% zinc. Bulk materials handling, leaching, filtration, removal of soluble impurities, and electrolysis will interest chemical engineers here.

Granite City Steel Co., Granite City, Ill., Trip W-2, 66 men.

Hot and cold rolled steel is produced in coils and sheets at the rate of 1,200,000 tons/year. Heavy steel-forming machinery, conveyers and the inspection department will be seen. The continuous and rapid processing of electrolytic tin plate here is also of interest.

Fisher Body Co., Chevrolet Assembly Plant, St. Louis, Trip W-3.

Large-scale continuous production assembly lines will be seen in operation. Visiting engineers will be shown through the Fisher Body and Chevrolet automobile assembly plants.

Ladies' Program

The ladies will be well occupied while the men are attending technical sessions and plant trips. Mrs. S. L. Lopata and her committee have organized an interesting series of events which starts with the traditional get-acquainted coffee hour from 10 to 11:30 a.m. Monday in Ladies' Headquarters, Room 3, Hotel Jefferson.

At 12:30 p.m. Monday, a gala luncheon at the private Columbian Club, Eighth and Locust Streets, will feature a "sit-down tour of St. Louis" with slides. Carl Weber will "M.C." the program, whose theme is "St. Louis' Colorful Past and Bright Future." Charles van Ravenswaay, director of the Missouri Historical Society, will give an illustrated talk on the Lewis and Clark Expedition and early St. Louis homes. Mary Powell of the City Art Museum will tell about some of the outstanding works of art there in her talk "History of the City Art Museum and its Relation to St. Louis." Malcolm W. Martin, secretary-treasurer of the St. Louis Educational Television Commission, will discuss "Educational TV on the St. Louis Scene." Station KETC, Channel 9, the first community-sponsored noncommercial educational television station in the country, will have been in operation in St. Louis about two months at that time.

On Tuesday tours will start from the Jefferson at 10:00 a.m. One will be a tour of the city to follow up Monday's "sit-down tour." Another will be a visit to Anheuser-Busch, Inc. There may also be a combination trip to Anheuser-Busch and to near-by Cherokee Cave, "the only cave in the world in the midst of a city," which features an Arabian Nights museum. At 1:00 p.m. the ladies will convene for luncheon at the Rose and Crown Room of Medart's Restaurant, where Moolah Temple Chanters will entertain them with Christmas Carols.

On Sunday, Monday, and Tuesday evenings the ladies will join the men

for parties, shows, and the banquet. At noon Wednesday, the out-of-town ladies may gather for an impromptu luncheon at the Jefferson. Between times the three large downtown department stores and many shops will be convenient for Christmas shopping. The stores are open until 8:30 p.m. Monday night. Card tables will be set up and cards on hand at all times in Ladies' Headquarters.

Dress will be informal for all events except the Awards Banquet, where dress is optional.

Entertainment

An unusual variety of events for Sunday, Monday, and Tuesday evenings has been lined up by the Entertainment Committee under chairman Richard M. Edwards of Mallinckrodt.

Sunday night from 8:00 to 10:00 p.m. the convivial "Get-Acquainted Party" will be held in the gilt and glitter of the Hotel Jefferson's Gold, and Crystal rooms. Here as at other meetings, old friends will be hailed and new friendships launched on a sea of conversation. Refreshments will be on hand. Admission will be by badge, dress informal.

For Monday night two events are scheduled, in addition to the spontaneous dinner and sightseeing parties to which Monday nights are usually given over. Typical of old St. Louis will be a "Mellerdrammer" from 8:30 to 10:15 p.m. on the Showboat S. S. Goldenrod, where the audience freely cheers the stalwart hero and hisses the dastardly villian. One boat, that can't be missed, the Goldenrod rides permanently at anchor on the downtown Mississippi levee.

Without even leaving the Jefferson, others can see a humorous but pointed movie "The Man in the White Suit" with Alec Guiness, about a chemist who invented an indestructible fiber. Admission to the movie is by badge and tickets for the Showboat will be available to preregistrants and to later registrants while they last.

A cocktail party at 6:30 p.m. in the Ivory, and Crystal rooms will precede the big event of Tuesday evening, the Awards Banquet. The banquet and its interesting program will be held in the Gold Room. Afterwards Hal Havird's orchestra and songstress will furnish music for dancing in the Ivory Room or sitting-out in the adjoining Crystal Room, and a cash bar will be provided. Dress will be optional.

Throughout the meeting a member of the Entertainment Committee will be stationed at the Information Center to answer questions on local theatre events, night clubs, restaurants and other attractions of the St. Louis area.

The End

NEWS

(Continued from page 66)

NATIONAL SCIENCE FOUNDATION GRANTS

In its Third Annual Graduate Fellowship Program, for 1954-55, the National Science Foundation will award more than 700 grants for one year of scientific study toward advanced degrees or for postdoctoral work.

The fellowships are awarded to American citizens who will begin or continue their studies at the graduate level in the engineering, mathematical, physical, biological, and medical sciences.

Students entering graduate school for the first time or those who have less than a year of graduate study will receive annual stipends of $1,400. Fellows who need one final academic year of training for the doctoral degree will receive $1,800. Fellows between these groups will receive $1,600. Postdoctoral fellows will be granted $3,400 annually. Dependency allowances for all married Fellows, tuition and laboratory fees, and limited travel allowances will also be provided.

National Science Foundation graduate Fellows may attend any accredited nonprofit institution of higher education in the United States or similar institutions abroad.

Applications may be obtained from the Fellowship Office, National Research Council, Washington 25, D.C. The closing dates for receipt of applications are Dec. 15, 1953, for postdoctoral applicants and Jan. 4, 1954, for graduate students. Selections will be announced by April 1, 1954.

FREQUENCY-RESPONSE MEETING IN NEW YORK

A symposium on frequency response to be held in New York on Dec. 1 and 2 by the American Society of Mechanical Engineers, Instruments and Regulators Division, will be of interest to many chemical engineers, according to S. D. Ross, A.I.Ch.E. representative for the division.

Among the topics will be a survey of sine wave generators with special emphasis on the low-frequency pneumatic output type required for process control work; practical aspects of frequency-response techniques and simple design criteria useful to engineers and technicians in the field; examples of application of the techniques to control studies on a chemical plant unit and design of controllers.

Further information may be secured from Stephen P. Higgins, Jr., Minneapolis-Honeywell Regulator Co., Wayne and Roberts Ave., Philadelphia 44, Pa.

MARGINAL NOTES

(Continued from page 30)

characteristics, common methods of manufacture, common grades, forms and purities, usual containers, and important uses. One of the shortest entries is that for sodium zirconium sulfate.

The jacket of the second edition of this book says, "All the principal facts about commercial chemicals from Abalyn to Zirconium Oxide revised and brought up-to-date for handy reference." So this reviewer spent an hour and never did find "Abalyn." This brings up the most serious defect of the book—no index. An index in the form of uncut page proof for pages 589 to 631 has been prepared and it is hoped that the book finally offered for sale will contain this index.

In no way can the book supplant a chemical handbook because few physical constants are listed, nor can it be considered a chemical dictionary. On the other hand (with the proper index), it is a ready source of information. Methods of manufacture are also usually listed, but for many organic compounds of rising importance only minor, and at times obsolete, processes are mentioned. The appendix includes summaries of the U. S. Caustic Poison Act, the Food, Drug and Cosmetic Act, the Federal Insecticide, Fungicide and Rodenticide Act, and Official Tares of the New York Board of Trade.

For those familiar with the first edition, organization of material is the same in this edition; data on grades, containers, and uses of products in the first edition have been brought up to date, and new commercial chemicals have been added.

An Investment for the Engineer

Kinetics and Mechanism. A Study of Homogeneous Chemical Reactions. A. A. Frost and R. G. Pearson, John Wiley & Sons, Inc., New York (1953). 332 pp., $6.00.

Reviewed by Ralph R. Wenner, assistant research director, Central Research Department, Monsanto Chemical Co., Dayton, Ohio.

The chemical engineer who is concerned with kinetics as a means for correlating and evaluating reaction rate data and as a tool for converter design will be disappointed in this book. This volume is concerned with homogeneous reactions in batch or closed systems—only five pages are devoted to flow systems. Chemical engineering kinetics usually involves analyses based on simultaneous rates of reaction, heat and

mass transfer for multiphase systems, and is still largely in the development or "free-wheeling" stage. Nevertheless this book is a real contribution to the field of chemical kinetics and is recommended for the serious student or practicing engineer who is interested in acquiring a sound background of classical reaction kinetics before tackling the more complicated industrial applications.

Applications of fundamental kinetic principles to the derivation of the integrated forms of the many types of reaction rate equations are presented in a logical manner. Included are chapters presenting good introductions to the treatment of reaction rates by collision theory and the activated complex or transition-state theory. Chapters presenting brief treatments of homogeneous catalysis in the gas and liquid phase and the application of kinetics to chain reactions are also included.

The final chapter which is devoted to a study of reactions whose mechanisms have been investigated by kinetic and other methods is prefaced by the following pregnant statements (p. 240):

> **The examples chosen will show that the kinetic method, including not only determinations of reaction rates and orders but also the changes in these rates and orders with changing conditions, is the best approach to reaction mechanisms. However, they will also show that kinetics is incomplete by itself and must be liberally supplemented with other studies. Frequently there are several mechanisms which are kinetically indistinguishable; frequently the mechanisms deduced from kinetics alone are too vague as to the exact processes taking place.**

The science of kinetics, like thermodynamics, pays dividends in proportion to the invested effort; if the engineer means business, this is a good book to own.

Books Received

Development of Processes for Production of Fused Tricalcium Phosphate. Tennessee Valley Authority, Wilson Dam, Ala. Chemical Engineering Report No. 7. Compiled by J. C. Brosheer and T. P. Hignett. U. S. Government Printing Office (1953). 143 pp. 40 cents.

Distillation Literature, Index and Abstracts. 1946-52. Arthur and Elizabeth Rose. Applied Science Laboratories, Inc., State College, Pa. (1953) $25.00.

Elements of Heat Treatment. George M. Enos and William E. Fontaine. John Wiley & Sons, Inc., New York (1953), 286 pp., $5.00.

Laboratory Experiments in General Chemistry and Semi-Micro Qualitative Analysis. George W. Watt and L. O. Morgan. McGraw-Hill Co., Inc., New York (1953). 228 pp. $3.50.

PEOPLE

McCABE, ENGINEERING DEAN AT BROOKLYN

Warren L. McCabe, President of the American Institute of Chemical Engineers (1950) and until recently vice-president and director of research of the Flintkote Co., Whippany, N. J., has returned to the field of engineering education as dean of the College at the Polytechnic Institute of Brooklyn. As dean of the College, Dr. McCabe, who took his three chemical engineering degrees, B.S., M.S. and Ph.D. at the University of Michigan, heads the undergraduate school with its two divisions, the day session with its dean of men and the evening undergraduate session with its administrative officer, the director of the evening session.

Before joining Flintkote Dr. McCabe was professor of chemical engineering and head of the department at Carnegie Institute of Technology.

Over a period of several years Dr. McCabe served the A.I.Ch.E. well, in such capacities as Director (1942-44, 1946-48), Vice-President (1949), and as member of many committees, including Papers, Student Chapters, Chemical Engineering Education and Accrediting, Awards, and others. In 1937 he received the William H. Walker Award of A.I.Ch.E. given in recognition of his creative contributions to the literature of chemical engineering.

The Chemical Plants Division of Blaw-Knox Co. recently announced the appointment of **M. R. Wingard** as sales engineer. He will be located at the Western headquarters in Tulsa, Okla., and will offer the company's processes and engineering construction services to chemical, petrochemical, and industrial clients in a nine-state area. Mr. Wingard is a graduate of the University of Akron and has done graduate work at the University of Michigan.

Jack C. Hutchison, formerly branch manager in Cincinnati, has been advanced to the position of New York assistant general branch manager of the Monsanto Chemical Co. organic chemicals division sales organization. He joined the company in 1941, becoming a member of the engineering sales department in 1942. He received his B.S. degree in chemical engineering from the University of Tennessee in 1935.

George G. Crewson, director of engineering, and a director of Buffalo Electro - Chemical Co., Inc., has been selected by the Western New York Section of A.I.Ch.E. to receive the second annual Professional Achievement Award. This means a general recognition of his outstanding service to both the local section and to the national organization for his contributions to the chemical engineering profession as a whole. Mr. Crewson is also engineering consultant on the staff of the vice-president of the Chemical Division of Food Machinery & Chemical Corp., of which Becco is now a unit. Mr. Crewson's career was formally launched upon his graduation from the University of West Virginia in 1910. Through the next eleven years he served Eastern Steel Co., Roessler & Hasslacher and Du Pont, in many phases of engineering, research, and development.

L.W. BASS TO SUPERVISE PROJECT IN EGYPT

Lawrence W. Bass, President of A.I.Ch.E. (1945), and associated with Arthur D. Little, Inc., since 1952, has left for Egypt to administer that organization's industrialization project for that country. For twenty-five years Dr. Bass served in an executive capacity on the staffs of several companies—as director of research for the Borden Co., assistant director of Mellon Institute, and director of the New England Industrial Research Foundation. Before joining Arthur D. Little, Inc., he was vice-president of the U. S. Industrial Chemicals, Inc., and also was associated for several years with Air Reduction Co.

Leon Davidson has recently joined the staff of Nuclear Development Associates, Inc., White Plains, N. Y. He has been associated with the atomic energy field for ten years, recently on the Operations Analysis Staff of the general manager at the A.E.C. Washington headquarters.

Edward A. Mason is now senior engineer with Ionics, Inc., of Cambridge, Mass. He was formerly assistant professor of chemical engineering at the Massachusetts Institute of Technology. Mr. Mason received the Sc.D. degree from M.I.T. in 1950 and served as director of the Bangor Station of the M.I.T. School of Chemical Engineering Practice from 1950 to 1952.

WHITE, EXEC. VICE-PRES. OF VITRO CORP.

George White, Jr., was recently elected by the board of directors to the position of executive vice-president of Vitro Corporation of America, New York, N. Y. He has been with the company since 1946, as a director and vice-president of its parent, The Vitro Manufacturing Co., and has served as chairman of the board and president of another subsidiary, Vitro Chemical Co. He is now executive vice-president, a director and member of the executive committee of the three companies.

Mr. White received a B.S. degree from Princeton in 1933 and then acted as a technical assistant for the Shell Petroleum Corp. for the next three years. Later he joined the M. W. Kellogg Co. as a process engineer. From 1943 to 1946 he served the government's Rubber Reserve Co. as deputy director. Following his war service, he joined Vitro as a division engineer and was later made director of project management.

Nathan Gilbert, who has been with the process development branch of T.V.A. at Muscle Shoals since 1942, has recently resigned his position to accept a teaching post at the University of Cincinnati. At T.V.A. he perfected the development of a process for reconversion of wood waste into molasses suitable for animal feed and was responsible for continuing the work of the forest products laboratory of the U.S.D.A. He received his B.S. degree in chemistry from the University of California and a Ph.D. degree in chemistry from the University of Wisconsin.

Theodore Vermeulen, professor of chemical engineering at the University of California, has received a Fulbright Award for Belgium, and will lecture on plant design at the universities at Liege and Ghent during the current academic year. While in Europe he will also participate in the research program of the Institute of Petroleum in Paris, where he will work especially on the phase-equilibrium relations and apparatus requirements for solvent extraction of lubricating oils.

James G. Dustin, formerly assistant superintendent of the wet starch division, A. E. Staley Manufacturing Co., is now production superintendent. Mr. Dustin joined the Staley Co. in 1938 following his graduation from the University of Iowa.

Melvin E. Clark was recently appointed vice-president—marketing for Frontier Chemical Co., with headquarters in Wichita, Kan. In his new position, Mr. Clark will have responsibility for sales, market research, advertising, traffic, and other marketing functions. Prior to this position he was general product manager, Michigan Alkali Division, Wyandotte Chemicals Corp., Wyandotte, Mich. Mr. Clark received his B.S. degree from the University of Colorado in 1937.

DEAN, PAULLUS IN NEW JOBS AT MONSANTO

Carlton M. Dean has been appointed manager and **Marvin R. Paullus** assistant manager of the engineering sales department, organic chemicals division Monsanto Chemical Co. Mr. Dean, who succeeds **Thomas R. Harney**, recently retired, joined Monsanto's production staff in 1917, and has been associated with engineering sales since 1934. He was graduated from M.I.T. in 1917, with a B.S. degree in chemical engineering.

Mr. Paullus, who joined Monsanto as a sales trainee in 1941, received his B.S. degree in chemical engineering from Purdue University. He has been concerned primarily with design and sales and was in the company's general engineering department for two years.

Walter E. Smith, Jr. has joined the staff of the Los Alamos Scientific Laboratory, University of California. He was formerly assistant factory superintendent of the Grove Farm Co. at Puhi, Kauai, Hawaii. He received his B.S. in chemical engineering from the University of Colorado at Boulder.

James A. Wilson has recently been appointed production manager of the chemical phosphates department of International Minerals & Chemical Corp. Mr. Wilson has had a broad experience in chemical processing and plant operations. In his previous position he served as production manager of the Merrimac Division, Monsanto Chemical Co., Everett, Mass. He received his B.S. degree in chemistry from Clemson College and did postgraduate work at Massachusetts Institute of Technology.

MOULTON HEADS NEW DEPARTMENT AT SEATTLE

R. Wells Moulton has been named head of the newly constituted department of chemical engineering at the University of Washington, Seattle, according to a recent announcement of the Board of Regents of the University. Dr. Moulton previously headed the division of chemical engineering and has taught at Washington since 1941. Before that year he was in industrial practice with Union Oil Co., Los Angeles as a process engineer engaged on pilot-plant development and on design of commercial refinery units.

Dr. Moulton has made many research contributions and has served in various ways in A.I.Ch.E. and in the chemical engineering division of the American Society for Engineering Education.

Norman E. Hathaway, sales manager of the industrial chemicals department, Davison Chemical Corp., has been granted a six months' leave of absence by the company to serve as director of the chemicals and rubber division of the chemical, rubber and forest-products bureau in the successor agency to the National Production Authority, which is being organized by the Department of Commerce. Joining Davison in 1946, he was first in technical sales, then director of technical service, later field service engineer, and was appointed to his present post in 1951.

The promotion of **S. Cottrell** to the position of vice-president of the Mathieson Agricultural Chemicals Division, Mathieson Chemical Corp., with headquarters in Little Rock, Ark., was recently announced. He will continue as director of operations of the division's seven plants. Before joining the company in 1949 as operations manager of the Mathieson Hydrocarbon Chemicals Corp., he was associated with American Potash and Chemical Corp. and Monsanto Chemical Co. in executive capacities.

C. H. Marshall has been promoted to the rank of technical specialist in the technical service division at the Baytown, Texas refinery, Humble Oil & Refining Co. In this capacity his activities will be primarily in the fields of process designs of new installations and following their initial operations in the plant. Mr. Marshall received his B.S. degree in chemical engineering from Louisiana Polytechnic Institute.

(More about People on page 81)

CLASSIFIED SECTION

Advertisements in the Classified Section of Chemical Engineering Progress are payable in advance at 15c a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed one six-line Situation Wanted insertion (about 36 words) free of charge a year. More than one insertion to members will be made at half rates. In using the Classified Section of Chemical Engineering Progress it is agreed by prospective employers and employees that all communications will be acknowledged, and the service is made available on that condition. Boxed advertisements are available at $15 a column inch. Size of type may be specified by advertiser. In answering advertisements all box numbers should be addressed care of Chemical Engineering Progress, Classified Section, 120 East 41st Street, New York 17, N. Y. Telephone ORegon 9-1560. Advertisements for this section should be in the editorial offices the 15th of the month preceding the issue.

SITUATIONS OPEN

SENIOR PROCESS ENGINEER—Heavy responsibility in process design and development for a Ch.E. with eight to ten years' experience in petroleum or petrochemical fields. This is a permanent position with an East Coast organization known the world over for accomplishments in the design and development of oil refineries and chemical plants. The man selected must have the potential to supervise other senior process engineers. High salary. Traveling and moving expenses paid. Unusually liberal vacation, insurance and pension plans. Our staff knows of this opening. All replies held in strictest confidence. Please write details of experience, education, salaries received and initial salary requirements. Box 1-10.

CHEMICAL ENGINEER — SALES CORRESPONDENT — Progressive Midwest manufacturer has opening for ambitious young engineer, preferably chemical, to handle correspondence and gradually assume responsibilities of office management. Will be given opportunity to learn filtration from both technical and practical viewpoints and may develop without limitation into field sales work. Salary open. Submit résumé and salary desired. Box 2-10.

FILTRATION ENGINEER—Progressive manufacturer in Illinois has attractive opening for filtration engineer. Five years' or more experience desired. Duties will include both test work in laboratory and contact with customers in the field. Salary open. Submit résumé and salary request. Box No. 5-10.

CHEMICAL ENGINEER — For pilot plant work in growing medium-sized chemical company manufacturing synthetic resins and polymers. Experience in synthetic rubber, or other vinyl type polymerizations desirable but not essential. Outstanding opportunities for advancement in development or production. Box No. 6-10.

VINYL POLYMER CHEMIST—A well established national manufacturer is expanding its line of products to include polyvinyl acetate emulsions. A chemist or chemical engineer with specific experience in polyvinyl acetate polymerization is needed to take charge of the manufacture and product development of these new products. Excellent opportunity to grow with an expanding organization. Please give details of education, experience and salary desired. Our employees have been informed of this advertisement. Box 20-10.

SITUATIONS WANTED

A.I.Ch.E. Members

CHEMICAL PROCESS ENGINEER—B.S. 1941. Desire morning work in New York area to permit study for advanced degree afternoons and evenings. Experienced in economic evaluation, design, and operation of nitrogenous fertilizer, refining, natural gasoline, and petrochemical plants. If interested, please write for a résumé. Box 3-10.

CHEMICAL ENGINEER—PRODUCTION MANAGEMENT—Age 36. M.Ch.E. Twelve years' experience. Resident manager of alcohol plant; chief engineer of eight plant organization; assistant to vice president in charge of production. Retained by president as only technical member, to aid in liquidation of company. Seeking responsible position in production, management or plant engineering. Box 4-10.

CHEMICAL ENGINEER—B.Ch.E. (five years) 1950. Recent veteran. Pilot plant and production experience in fine and heavy organics. Excellent college background in economics. Desire position relating experience with technical service and market development activities. Box 7-10.

YOUNG MAN—B.Ch.E. 1951. Age 25. No experience wishes position with future. Box 8-10.

CHEMICAL ENGINEER—Twenty years' diversified experience in research and development, process improvement, maintenance, design, estimating, consulting, pilot plant operation, production. Capable research director or plant engineer. Desire position on West Coast, preferably San Francisco Bay area. Box 9-10.

CHEMICAL ENGINEER—B.S.Ch.E. University of Michigan 1943. Married. Age 31. Ten years' experience in petrochemicals process engineering and production including supervision. Prefer Midwest or Great Lakes area. Box 11-10.

CHEMICAL ENGINEER—B.Ch.E. 1949. Age 28, married. 4½ years' experience includes: technical service, laboratory production control, process engineering, pilot plant investigations, and production supervision. At present assistant general foreman, $475 a month. Seeking responsible position in N. Y.-N.J.-Conn. area. Box 12-10.

DEVELOPMENT OR PRODUCTION ENGINEER—With fifteen years' diversified experience in manufacture of organic chemicals: production, development, and design. Box 13-10.

M.S. CHEMICAL ENGINEER—Licensed. Ten years' experience in production, pilot plant supervision. Box 14-10.

CHEMICAL ENGINEER—Twenty years' experience. Thorough background pertaining to the development and manufacturing of catalysts, catalytic oxidation processes, surface active agents, and polyester resins. Position as director or assistant director of development department desired. Box 15-10.

EXECUTIVE ENGINEER—Age 35. N. Y. P. E. license. Broad experience includes management of plant production, process development and plant design for the chemical and petroleum industries. Desire responsible and challenging position with a progressive chemical company or engineering contractor. Box 16-10.

CHEMICAL ENGINEER—Ten years' experience in product and process development of refinery operations, oil blending, grease compounding, and manufacture of automotive and specialty products. Registered professional engineer. Desire responsible position with opportunity for advancement. Box 17-10.

SALES—Live wire chemical engineer, bored with research and development, desires challenging opportunity in chemical or process equipment sales. Six years' diversified experience in organic coatings, explosives and allied chemicals. B.Ch.E. Age 28, single, personable, good appearance. Box 18-10.

CHEMICAL ENGINEER—M.Ch.E. Age 31. Nine productive years with leading dry food manufacturer. Experience in product and process development, equipment design and installation in supervisory capacity. Patents. Mature, personable, seek administrative position. Box 19-10.

PROCESS DESIGN ENGINEER — M.Ch.E. P.E. Nine years' chemical-mechanical experience in design and operation of process equipment. Ch.E. unit operations, material balances, evaluations, steam power generation. Proposals and some sales. Box 21-10.

PROJECT ENGINEER—Ten years' experience. Thoroughly familiar all phases complete chemical plant design, estimation, purchasing and construction. Projects of all sizes with locations in U. S., Europe and South America. Best references. Married, family. Age 35. Box 22-10.

ACADEMIC POSITION—Chemical Engineering Ph.D., P.E. Age 35, family. Active member A.I.Ch.E. Seek teaching position with responsibility and opportunity. Twelve-month basis preferred. 8½ years' teaching, industrial, and consulting experience. Publications. Excellent references. Available February or June, 1954. Box 23-10.

PEOPLE

(Continued from page 79)

PERSONNEL CHANGES AT DU PONT

Carl S. Oldach manager of the technical section of the Du Pont plant at Victoria, Tex., has been promoted to the position of assistant plants technical manager in the polychemicals department in Wilmington. At the same time, **John V. E. Hardy** was advanced from assistant technical manager at the Victoria plant to succeed Dr. Oldach, and **Robert B. Goodwillie,** technical superintendent at the Belle, W.Va. works, was promoted to Mr. Hardy's former post.

Since joining Du Pont as a senior chemical engineer at the Experimental Station in 1940, Dr. Oldach, has been assistant technical superintendent at the Belle Works and a research supervisor in Wilmington where he worked on the design of the Victoria plant.

Mr. Hardy started with Du Pont in 1939 and spent a number of years in research at the Experimental Station, going to the Victoria plant as technical superintendent in 1951.

Mr. Goodwillie began with Du Pont after receiving a M.S. degree in chemical engineering from M. I. T. He worked in research in Wilmington and in the technical section of the Sabine River Works at Orange, Tex., before going to the Belle plant last year.

I. H. Munro has been serving for the past several months as assistant to the executive vice-president and **William E. Dugan, Jr.** as assistant chief engineer, Solvay Process Division, Allied Chemical & Dye Corp.

A graduate of Colgate University, Mr. Munro joined Solvay's engineering department in 1935, after receiving his M.S. in chemical engineering at Massachusetts Institute of Technology. Subsequently he was appointed assistant chief engineer and chief engineer.

Mr. Dugan, a chemical engineering graduate of Carnegie Institute of Technology, has been with Solvay Process engineering department since 1946. In 1952 he was transferred to the Baton Rouge, La., plant as project manager for a major soda ash expansion program.

David Brown is now director of process development, Scientific Design Co., Inc. Prior to this appointment he served Shell Development Co. as senior development engineer in the process engineering department. Mr. Brown was also associated with M. W. Kellogg Co. as an engineer before entering the U. S. Navy in 1944. He has been associated with Thompson Weinman & Co. as a chemist and the Standard Oil Company of California as an engineer. He received his A.B. degree in chemistry from Swarthmore College in 1938 and in 1940 his M.S. degree in chemical engineering from Massachusetts Institue of Technology.

L. W. Sessions, sales representative of the organic chemicals division, Monsanto Chemical Co., was recently appointed to a two-or three-year post in London, England, with Monsanto Chemicals Ltd. Mr. Sessions will be associated with the development group of the sales division of the British company. He joined Monsanto in 1946 as project engineer in the company's John F. Queeny plant.

Carl S. Carlson, formerly of the Standard Oil Development Co., has been appointed director of research of Morton Salt Co., Chicago. He will be in charge of the laboratory which will be constructed at Woodstock, Ill. He received his B.S. (1935), M.S. (1937), and Ph.D. (1939) degrees from Pennsylvania State College.

(People continued on page 82)

NEWS ABOUT PEOPLE

(Continued from preceding page)

Howard R. Batchelder has recently joined the staff of Battelle Institute, Columbus, Ohio, as an associate consulting chemist, coordinating research devoted to non-fuel uses of coal and chemicals derived from coal. Prior to joining Battelle, Batchelder was, for five years, in charge of gasification planning at the United States Bureau of Mines' fuels demonstration plant, Louisiana, Mo. While there he also served as consultant on gasification to the Chief of the Division of Fuels Technology for the Bureau's Region VIII. Before joining the Bureau of Mines he was employed as technical director by the Institute of Gas Technology, Chicago, and had also been associated with the United Gas Improvement Co., Philadelphia, and the Standard Oil Co. of Indiana, Whiting, Ind.

Alden R. Loosli has been named manager of the newly formed market research and development department at Calco Chemical Division, American Cyanamid Co., Bound Brook, N. J. He will continue in his present post of assistant to the general manager. He began with Calco in 1937 as a student trainee and has held supervisory positions in various production departments. After a period of sales training he was appointed assistant sales manager of the rubber chemicals department in 1947. In 1950 he was named assistant manager of the intermediate and rubber chemicals department when they were consolidated. Mr. Loosli received a B.S. in physical sciences from the University of Chicago.

Corn Products Refining Co. has recently appointed **William E. Brinker** chief engineer. He was appointed director of engineering of the company's chemical division in 1944, and assistant chief engineer in 1948. Prior to going with the company, he was associate professor and head of the department of chemical engineering, Technological Institute, Northwestern University. Mr. Brinker received his B.S. and Ph.D. degrees in chemical engineering from the University of Pittsburgh.

Necrology

H. V. BERG

Holger V. Berg, retired, died recently. A graduate of the Pharmaceutical College at Copenhagen, he was associated early in his career with the Krebs Pigment & Chemical Co., Newport, Del. first as superintendent, and then as manager and vice-president.

INDEX OF ADVERTISERS

Advertising Offices

New York 17—Lansing T. Dupree, Adv. Mgr.; Paul A. Jolcuvar, Dist. Mgr.; 120 E. 41st St., Oregon 9-1560.

Chicago 4—Richard R. Quinn, Dist. Mgr., 20 E. Jackson Blvd., Room 800, Webster 9-2225.

Cleveland 15—Douglas H. Boynton, Dist. Mgr., 1836 Euclid Ave., Superior 1-3315.

Pasadena 1—Richard P. McKey, Dist. Mgr., 465 East Union St., Ryan 1-8779.

THE PRESIDENT SAYS

As I write, another A.I.Ch.E. election is in progress. I have seen the tabulation of nominating ballots. All of us are indebted to Messrs. White, Adler, Dorsheimer, Malakoff, Morton, and Wolff who carried out the rather tedious duties of tellers. We mailed out 4,805 ballots and received back 1,578, about one third.

For nomination a candidate must receive votes from at least one per cent of those qualified to vote (in this case, 48 votes). There are six such names for Vice-President and nineteen for Director. Formal acceptance of the nomination by the candidate is required. For Director the highest twelve accepting are listed on the ballot. In all cases the order of listing is in descending order of votes received. Some years ago the first four names in the list of twelve were usually elected. Probably few voters knew the candidates and checked the first four names either because that was easiest or because it seemed proper since these had received the most nominating votes. Latterly, increasing interest in elections has changed this somewhat, though there is still a strong tendency to elect those high up on the list. Nominating ballots have therefore been important in deciding these contests.

In recent years sections have done some torch-bearing for their candidates and, within reason, I think this is good. Some of our members are afraid this situation will get out of hand and that large sums of money will be spent on electioneering. I doubt that there is enough incentive. At any rate, a professional organization, such as ours, can not tolerate objectionable practices and we should all be alert to avoid developments which could give rise to them. There are certain areas of the United States where concentration of voting members is high. Members in one of these areas could virtually control our elections if they chose to do so and it is notable that they do exercise restraint. This is the kind of spirit which ought to characterize a group functioning at the high level exemplified by A.I.Ch.E.

It seems evident that Constitutional provisions for nomination and election of officers and directors were geared to a time when our membership was quite small and highly concentrated so that members knew each other to a great degree. Now we are comparatively numerous and spread out all over the United States. I believe we need a better way to identify good candidates for office. The figures cited above do not tell quite the whole story. In addition to those mentioned there were over a hundred more names on the nominating ballots. Certainly quite a few of those who received the necessary number of votes will decline to run. Four of the six candidates for Vice-President have already so indicated.

It has been suggested that Council might act as a nominating committee since it is in a position to watch members doing Institute work and to know who could be expected to perform effectively. This is not a bad idea, but I like even better a suggestion of a nominating committee comprising members both in and out of Council. In any event it seems reasonable to me to put the job in the hands of a properly specified nominating committee instead of leaving it to an unorganized procedure as at present. Potential candidates could be checked beforehand about their willingness to run and I believe we could provide a real choice for voters so that they could vote for one good candidate or another good candidate. Our nominating committee should function like a "non-partisan league," choosing candidates representing various viewpoints but being certain that all are worthy candidates, willing and able to work. I would favor continuing to stimulate interest in our Institute sections so that they would carry torches for people they favor and would bring these to the attention of the nominating committee.

* * * *

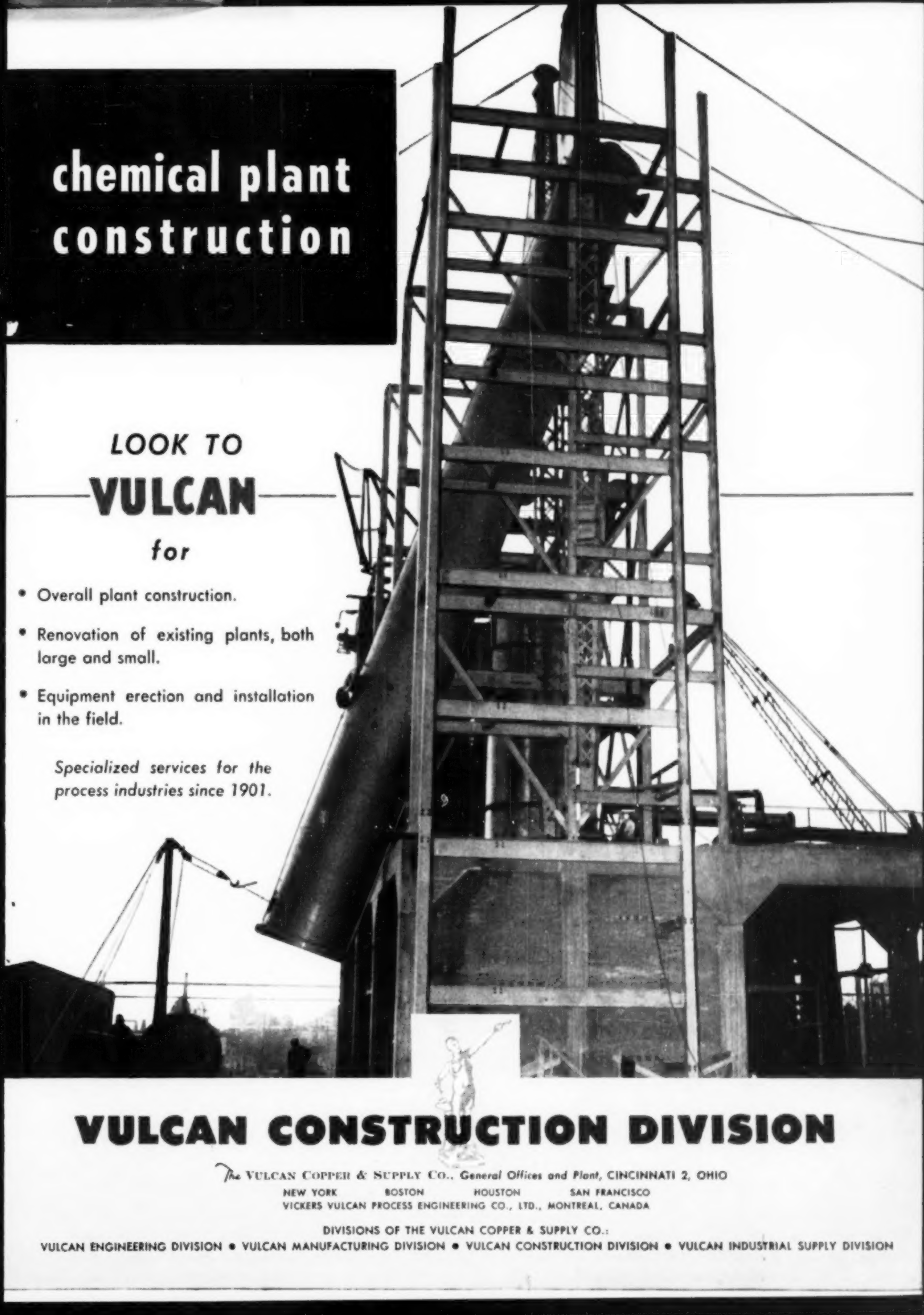
Those who read this column will surely have picked up the typographical error in next to the last sentence of the September column. "Affiliate" was, of course, intended.

* * * *

Chalk up another victory for the scheme I mentioned a couple of months ago for getting a study project accomplished! Earl Stevenson, who is just completing a term on Council, has been a tower of strength there. His reasonableness and good sense, his broad knowledge and skills have long been devoted to Institute purposes and never to better effect than during his term on Council. Recently I asked him to undertake a study project, choosing several other members to help. This project has to do with problems of housing for our Institute staff and for "C. E. P." staff. The mechanics of operating an organization comprising upwards of 13,000 members give rise to hundreds of thousands of transactions in the course of a year. Many of these involve paper work of one kind or another. So large and complex a job can not be done without people, furniture, machinery and space. We moved just a few years ago to get more space. Rents in Manhattan have been going up and up. To provide the facilities we believe we need will cost far more than we feel we can afford. Besides, it will be difficult, if not impossible, to maintain a good, workable situation merely by continuing to hunt for more and more rental space in Manhattan as our apparently inevitable growth continues.

This is a problem which Council believes must be handled with authority and decision—the reason why I asked Earl Stevenson to take on this study. After only a few weeks he reported to Council at our San Francisco session and it was perfectly evident that a comprehensive consideration had been given to such questions as improvement in our office procedures, advantages and disadvantages of keeping our staffs together, Manhattan versus other locations, ownership versus rental, possibilities of cooperating with other engineering societies on housing, and so forth. I mentioned recently the fine work being done by George Holbrook's Committee on the Future of the Institute. The Stevenson study is an example, and not the first, of a segment of the Institute's future which has moved up into the present. I am glad to be able to say that Council is dealing decisively with this matter and you may expect to hear more about our housing study in the months to come. What we aim to do is to give you more and better service at less cost.

W. T. Nichols



chemical plant construction
LOOK TO
VULCAN
for
• Overall plant construction.
• Renovation of existing plants, both large and small.
• Equipment erection and installation in the field.
Specialized services for the process industries since 1901.
VULCAN CONSTRUCTION DIVISION
The VULCAN COPPER & SUPPLY CO., General Offices and Plant, CINCINNATI 2, OHIO
NEW YORK BOSTON HOUSTON SAN FRANCISCO
VICKERS VULCAN PROCESS ENGINEERING CO., LTD., MONTREAL, CANADA
DIVISIONS OF THE VULCAN COPPER & SUPPLY CO.:
VULCAN ENGINEERING DIVISION • VULCAN MANUFACTURING DIVISION • VULCAN CONSTRUCTION DIVISION • VULCAN INDUSTRIAL SUPPLY DIVISION